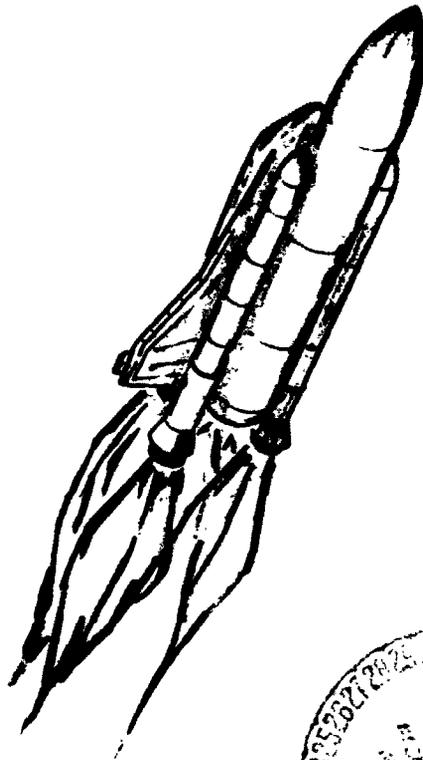


PRELIMINARY NONDESTRUCTIVE EVALUATION MANUAL FOR THE SPACE SHUTTLE



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FOR:
JOHN F. KENNEDY SPACE FLIGHT CENTER, FLORIDA
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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**PRELIMINARY NONDESTRUCTIVE EVALUATION MANUAL
FOR THE SPACE SHUTTLE**

APPENDIX TO FINAL REPORT

PREPARED UNDER CONTRACT NAS 10-8018 FOR THE:

**JOHN F. KENNEDY SPACE CENTER
NATIONAL AERONAUTICAL AND SPACE ADMINISTRATION
KENNEDY SPACE CENTER, FLORIDA 32899**

JULY 1974

**LOCKHEED-GEORGIA COMPANY
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16. Abstract This document constitutes a preliminary nondestructive evaluation (NDE) manual for the entire Space Shuttle vehicle, including the Orbiter, External Tank and the Solid Rocket Boosters. The document contains the NDE requirements for some 134 potential fracture-critical structural areas identified on these vehicles as possibly needing inspection during refurbishment turnaround and prelaunch operations. The requirements include critical area and defect descriptions, access factors, recommended NDE techniques, and descriptive artwork. Nine sections comprise the manual according to the following: Section 1-General; Section 2 through Section 6-Orbiter Structural NDE Requirements; Section 7-External Tank NDE Requirements; Section 8-Solid Rocket Booster NDE Requirements; and Section 9-Thermal Protection System Requirements (development area). The analysis necessary to derive the NDE requirements are based on ATP, PRR, and MCR-0200 baseline structural design drawings.			
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FOREWORD

This document is the Appendix to the final report on Contract NAS 10-8018, "Space Shuttle Structural Integrity and Assessment Study".

This preliminary Nondestructive Evaluation (NDE) manual was prepared for the Kennedy Space Center, National Aeronautics and Space Administration, to depict Space Shuttle structural areas and components that may require inspection during refurbishment for load-or environmental-induced damage and to describe anticipated service defects, access factors, and recommended NDE techniques. Detailed NDE procedures, not included in this manual, should be developed and validated when the design is firm and production structure is available. The material was developed from analysis of best available Space Shuttle design information current through April 1974.

The preliminary manual was developed at the Lockheed-Georgia Company, a division of the Lockheed Aircraft Corporation, Marietta, Georgia, by Mr. William M. Pless, who was the program Principal Engineer. The program was managed by Mr. William H. Lewis who is the NDE Technology Coordinator at Lockheed-Georgia. Structural analysis for identification of potential fracture-critical areas of Shuttle structure was performed by Mr. Gus Richmond, a structures analyst, and were also taken from interim reports from Contract NAS 3-16765, Fracture Control Design Methods.

Analysis and development of the NDE requirements for the Solid Rocket Booster were performed under the leadership of Ms. Judith Schliessmann at the Lockheed Propulsion Company in Redlands, California.

Mr. Rocco Sannicandro was the Contract Technical Representative for NASA at the John F. Kennedy Space Center, Kennedy Space Center, Florida.

The final report has been given the NASA identification NASA CR-134454 and this Appendix has been given the identification NASA CR-139180.

TABLE OF CONTENTS

<u>Title</u>	<u>Page</u>
INTRODUCTION	0-1
Purpose	0-1
Scope	0-1
Terminology	0-2
How to Use Manual	0-2
Glossary	0-5
Abbreviations	0-7
SECTION 1. GENERAL	1-i
SECTION 2. ORBITER FORWARD FUSELAGE STRUCTURE	2-i
SECTION 3. ORBITER MID-FUSELAGE STRUCTURE	3-i
SECTION 4. ORBITER AFT FUSELAGE STRUCTURE	4-i
SECTION 5. ORBITER WING STRUCTURE	5-i
SECTION 6. ORBITER VERTICAL STABILIZER STRUCTURE	6-i
SECTION 7. EXTERNAL TANK STRUCTURE	7-i
SECTION 8. SOLID ROCKET BOOSTER STRUCTURE	8-i
SECTION 9. THERMAL PROTECTION SYSTEM	9-i

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INTRODUCTION

Purpose

This manual presents engineering and analytical information pursuant to the establishment of complete nondestructive evaluation (NDE) techniques for critical structural areas of the entire Space Shuttle Vehicle. The requirements prescribed herein, developed in accordance with USAF MIL-M-38780, are intended to direct attention to anticipated structural problem areas where defects would prevent the items from performing their designed functions.

This manual has been based on design information current through November 1973. Design changes affected after this date or affected for a specific model may not be reflected in these preliminary requirements.

The inspections prescribed in this manual will be accomplished during refurbishment at periods specified by the applicable fracture control manuals prepared by or for the National Aeronautics and Space Administration for field or refurbishment levels, or during prelaunch and post assembly operations.

Scope

The nondestructive inspection requirements and techniques described herein apply largely to areas that are normally inaccessible for visual inspection methods.

The manual is divided into nine sections according to the following: Section 1 - General, Sections 2 through 8 - Structural NDE Requirements, and Section 9 - Thermal Protection System (TPS) requirements. The requirements include area description, location and class of probable service-induced defect, accessibility factors,

prescribed NDT technique(s), and necessary NDT equipment for each area. This information is intended to provide the basis for establishment of complete, detailed NDE procedures, which are not presently included in this document.

In addition to the NDE requirements, the document contains, for each critical area, descriptive art sufficient to show location on the vehicle and the probable location of cracks on the component/area.

Terminology

Such terms as left and right, upper and lower, front and rear, forward and aft, and clockwise and counter-clockwise when used refer to the vehicle as viewed on the center line from the rear, looking forward. All station locations, dimensions, and distances are given in inches unless otherwise noted.

How to Use the Manual

In essence, the manual consists of two parts: 1) a general part and 2) a part dealing with specific structural NDE requirements. The first part, Section I - General, describes the structural arrangement of the Shuttle vehicle, station diagrams, major assemblies, access provisions, NDT method description, basic NDT equipment calibration procedures and NDT safety factors. The second part is divided into eight (8) sections each describing the NDE requirements for the critical areas within a major assembly. The Shuttle is divided into numbered zones for designating and locating components and areas, as shown in the Shuttle area zone breakdown diagram in Figure 1-0 which provides the basis for arrangement of the sections. The sections correspond to specific structural groups occurring consecutively. A section may be further divided if several zones exist within the corresponding group. The numbered zones and sections are:

<u>Zone Designation</u>	<u>Zone Description</u>		<u>Manual Location</u>
100	Zone 1	Fwd Fuselage, Upper	Section 2, Fwd Fus Group
200	Zone 2	Fwd Fuselage, Lower	
300	Zone 3	Crew Module	
400	Zone 4	Mid Fuselage	Section 3 Mid Fus Group
500	Zone 5	Aft Fuselage	Section 4, Aft Fus Group
600	Zone 6	Wing	Section 5, Wing Group
700	Zone 7	Vertical Stabilizer	Section 6 Vert Stab Group
800	Zone 8	External Tank	Section 7, ET Group
900	Zone 9	Solid Rocket Booster	Section 8, SRB Group
1000	Zones 1-7	Thermal Protection System	Section 9

FIGURE 1-0. SPACE SHUTTLE VEHICLE ZONE BREAKDOWN

Individual zone numbers have been assigned to the major structural components defined by physical boundaries such as major bulkheads, splice joints or individual vehicles.

The structural zones are designated in this manual by a three-digit number such as 100 for the upper forward fuselage, 200 for the lower forward fuselage, 300 for the crew module, etc. Within a zone, the critical areas are numbered consecutively corresponding to the order, as far as possible, in which they may occur from forward

to aft, inboard to outboard, or lower to upper. For example, the number 202 corresponds to the NLG Trunnion Fitting in the lower forward fuselage group and 701 corresponds to the rudder forward spar in the vertical stabilizer group.

Section 2 consists of all 100, 200, and 300 serialized inspection areas, and Section 3 through Section 8 each consists of a single three-digit serialization.

GLOSSARY AND ABBREVIATIONS

Glossary

Angle of Incidence	The angle with respect to the local surface normal, with which a beam of energy impinges on the surface.
Bondline	A layer of adhesive between two faying surfaces, the interface between adhesive and faying element.
Buttock Line	Displacement in the $\pm y$ -direction in the x-y-z station coordinate system.
Critical Area	An area of structure or component which is determined either by analysis or experience to be prone to develop service defects in normal usage which would affect the serviceability of the equipment.
Depth of Field	The distance a magnifier can be moved toward or away from a subject, with the subject remaining within good focus. Depth of field decreases as the power of the magnifier increases.
Field of View	The area seen through a magnifier, the diameter of which is somewhat less than its focal length.
Fracture Critical	Refers to a critical area which, if it should fail because of defects, will lead to the loss of the structure and/or the loss of the vehicle or restrictive use of the structure or vehicle.
High-Q-Boost	Maximum dynamic pressure resulting directly from vehicle speed, atmospheric density, and wind velocity interacting with the vehicle.

Longitudinal	Refers to a direction along the longitudinal or x-direction of a vehicle; refers also to the ultrasonic wave whose particle motion is in the direction of propagation - a compressional wave.
Nondestructive Evaluation (NDE)	The broadest definition of nondestructive testing; includes testing, evaluation and interpretation of results.
Nondestructive Inspection (NDI)	Practically synonymous with NDE, used primarily when defect detection is of interest in production and service items.
Nondestructive Testing (NDT)	Refers to any technique that exploits a given energy form or material characteristic to assess properties or defects in materials without damaging the material in any way.
NDT Method	One of the broad technical disciplines consisting of the body of technology from which a multitude of NDT techniques can be derived (e.g., the ultrasonic NDT method).
NDT Technique	A specific arrangement of equipment and test variables derived from one of the NDT methods and exploited to perform a well-defined inspection effort (e.g., an ultrasonic shear wave technique to detect small fatigue cracks under a fastener head in 0.250-inch thick materials).
Operator, Inspector	An individual who is trained, skilled and certified in the use of one or more NDE methods and all its equipment for which he is responsible as an inspector.
Water Plane	An imaginary z-axis or horizontal plane designated by a range of numbers which increases from bottom to top surfaces of the Orbiter.

Structural Integrity The property of structure, in whole or in part, by which the structure is free from significant defects or physical property variances which would hinder or prevent its carrying out its design function during the service life of the structure.

Abbreviations

ABES	Air breathing engine system
AFT FUS	Aft fuselage
ASR	Acoustic sonic ringing
ASSY	Assembly
CM	Centimeter
CRT or CRO	Cathode ray tube or cathode-ray oscilloscope
ECS	Environmental control system
ET	External Tank
FRP	Fuselage reference plane
FUS STA	Fuselage station
FWD FUS	Forward fuselage
GSE	Ground support equipment
HRSI	High temperature reusable surface insulation
LH ₂	Liquid hydrogen
LO ₂	Liquid oxygen
LRSI	Low temperature reusable surface insulation
LWR	Lower
M	Meter
ME	Main engine(s), refers to one or all of the LO ₂ -LH ₂ engines on the Orbiter
MID FUS	Mid fuselage
ML	Mold-line
MLG	Main landing gear

MM	Millimeter
NDE	Nondestructive evaluation
NDI	Nondestructive inspection
NDT	Nondestructive testing
NLG	Nose landing gear
OML	Outer mold line
OMS	Orbital maneuvering system
ORB	Orbiter
RCC	Reinforced carbon-carbon
RCS	Reaction control system
REF	Reference
RSI	Reusable surface insulation
SRB	Solid rocket booster
SRM	Solid rocket motor
TBD	To be determined
TPS	Thermal protection system
TVC	Thrust vector control
UPR	Upper
VERT STAB	Vertical stabilizer
WP	Water plane
WSTA	Wing station

SECTION 1. GENERAL

This section contains vehicle structure descriptive information, nondestructive evaluation (NDE) method descriptive information, basic NDE calibration procedure, NDE equipment list, NDE safety considerations and accept/reject considerations.

SECTION 1
TABLE OF CONTENTS

	<u>Title</u>	<u>Page</u>
1.1	Description	1-1
1.2	Type of Construction	1-3
1.2.1	Forward Fuselage Structure and Crew Module	i-3
1.2.2	Mid-Fuselage Structure	1-6
1.2.3	Aft-Fuselage Structure	1-7
1.2.4	Wing Structure	1-9
1.2.5	Vertical Stabilizer Structure	1-10
1.2.6	Thermal Protection System (TPS)	1-11
1.2.7	Solid Rocket Booster (SRB) Structure	1-13
1.2.8	External Propellant Tank (ET) Structure	1-13
1.2.9	Surface Finish System - Orbiter	1-14
1.3	Inspection Access Provisions	1-15
1.4	NDE Symbols	1-21
1.5	Nondestructive Evaluation Methods	1-24
1.5.1	Optical Method	1-26
1.5.2	Penetrant Method	1-32
1.5.3	Magnetic Particle Method	1-39
1.5.4	Eddy Current Method	1-46
1.5.5	Ultrasonic Method	1-65
1.5.6	Radiographic Method	1-91
1.5.7	Microwave Method	1-104
1.5.8	Thermographic Method	1-109
1.6	NDE Equipment List	1-113
1.7	Safety Precautions in Using NDE Equipment	1-127
1.8	Acceptance/Rejection	1-132
1.9	References	1-133

SECTION 1
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
1-1	Shuttle Area Zone Breakdown	1-2
1-2	Major Subassembly Breakdown Diagram for Orbiter	1-4
1-3	Assembly Breakdown Diagram for Solid Rocket	1-12
1-4	Access Provisions for Space Shuttle	1-16
1-5	Station Diagram for Space Shuttle Vehicles	1-20
1-6A	Nondestructive Testing Method Symbols	1-22
1-6B	Ultrasonic Transducer and Eddy Current Probe NDE Illustrations	1-23
1-7	Illustrations of Some Types of Optical Borescopes	1-27
1-8	Direction and Field of View for Several Types of Borescopes	1-28
1-9	Penetrant Procedure - Portable or Field Application	1-33
1-10	Penetrant Procedure - Stationary	1-34
1-11	Magnetic Particle NDE Circular Magnetization Technique	1-41
1-12	Magnetic Particle NDE Longitudinal Magnetization Technique	1-42
1-13	Eddy Current Bolt Hole Inspection	1-49
1-14	Eddy Current Instrument Calibration Standard	1-51
1-15	Example - X-R Diagram for a Nortec NDT - 3 Eddy Current Instrument	1-55
1-16	Procedure for Assessment of Heat Damage by Eddy Current Conductivity	1-59
1-17	Example - Eddy Current Conductivity Assessment of Skin Panel After Loss or Heavy Damage of a TPS Tile	1-61
1-18	Reference Conductivity (IACS) and Rockwell Hardness Data for Bare Aluminum Alloys	1-63
1-19	Typical Applications of Ultrasonic Longitudinal- and Shear-Wave Techniques	1-67

SECTION 1 - LIST OF FIGURES (continued)

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
1-20	Initial Ultrasonic Longitudinal Wave Calibration	1-72
1-21	Initial Shear Wave Calibration - Lug Standard	1-75
1-22	Initial Shear Wave Calibration - Bolt Hole Standard	1-79
1-23	Principles of Ultrasonic Instrument Calibration - Honeycomb Bonded Structures	1-84
1-24	Principles of Ultrasonic Instrument Calibration - Honeycomb Bonded Structures - Typical CRT Presentation	1-85
1-25	Example - X-Ray Radiography Application, Illustrating Symbols, Film Placement, and Data Table	1-93
1-26	Radiographic Data Chart	1-95
1-27	X-Ray and Neutron Mass Absorption Coefficients for Various Elements	1-101
1-28	Diagram of a Portable Neutron Radiography Facility and Types of Film Imaging	1-103
1-29	Examples of Microwave NDE Reflection and Through-Transmission Systems	1-107

LIST OF TABLES

<u>Table Number</u>	<u>Title</u>	<u>Page</u>
1	Optical Test Instruments	1-31
2	Penetrant Groups	1-36
3	Type I, Method C, Group VII Penetrant Inspection Materials	1-36
4	First and Second Critical Incident Angles for Ultrasonic Waves Incident on a Metal	1-69

LIST OF TABLES (continued)

Table Number

5	Equivalent X-ray Films	1-97
6	Characteristics and Merits of Radioisotope Sources for Gamma Ray NDE	1-99
7	Letter Designations and Vacuum Wavelength Range of Major Bands of the Microwave Spectrum	1-105
8	Inspection Material and Equipment	1-114

SECTION 1.0 GENERAL

1.1 Description

The Space Shuttle is a system designed to place payloads and personnel into earth orbit, return them to earth, then be refurbished for additional orbital missions. The system consists of three basic assemblies which include the Orbiter, Solid Rocket Boosters (SRB) and the External Propellant Tank, as shown in the vehicle zone breakdown in Figure 1-1. The Orbiter, SRB Motor case, and certain portions of the SRB structure are completely recoverable and will be refurbished after each mission for future missions.

The system is launched in a vertical attitude, powered by firing the two SRB motors and the three $\text{H}_2\text{-LO}_2$ main engines on the orbiter. At a speed of about Mach 4.2, the SRB's terminate power and are jettisoned. The Orbiter continues to be powered into orbit by the 3 main engines fed by propellents from the external tank and jettisons the ET at orbit insertion. The Orbiter is capable of orbital maneuvers, rendezvous, orbit circularization and deorbit by deployment of the orbiter maneuvering system (OMS). Docking and attitude control is accomplished by use of the RCS engines mounted along x-y-z axis in forward and aft locations. After deorbiting, the Orbiter experiences high-temperature re-entry, performs cross-range flight, and makes a conventional runway landing.

The entire exterior surface of the Orbiter is covered with a nonmetallic thermal insulator whose thickness and material depend on the expected radiative equilibrium temperatures produced during re-entry. The wing leading edges and fuselage nose cap where re-entry temperatures are expected to exceed 2300°F are protected by a carbon-carbon material. Areas on the wing, fuselage, and vertical fin which experience temperatures between 1200°F and 2300°F are protected by tiles of ceramic high-temperature reusable surface insulation (HRSI). Remaining areas of the Orbiter which will experience temperatures less than 1200°F are

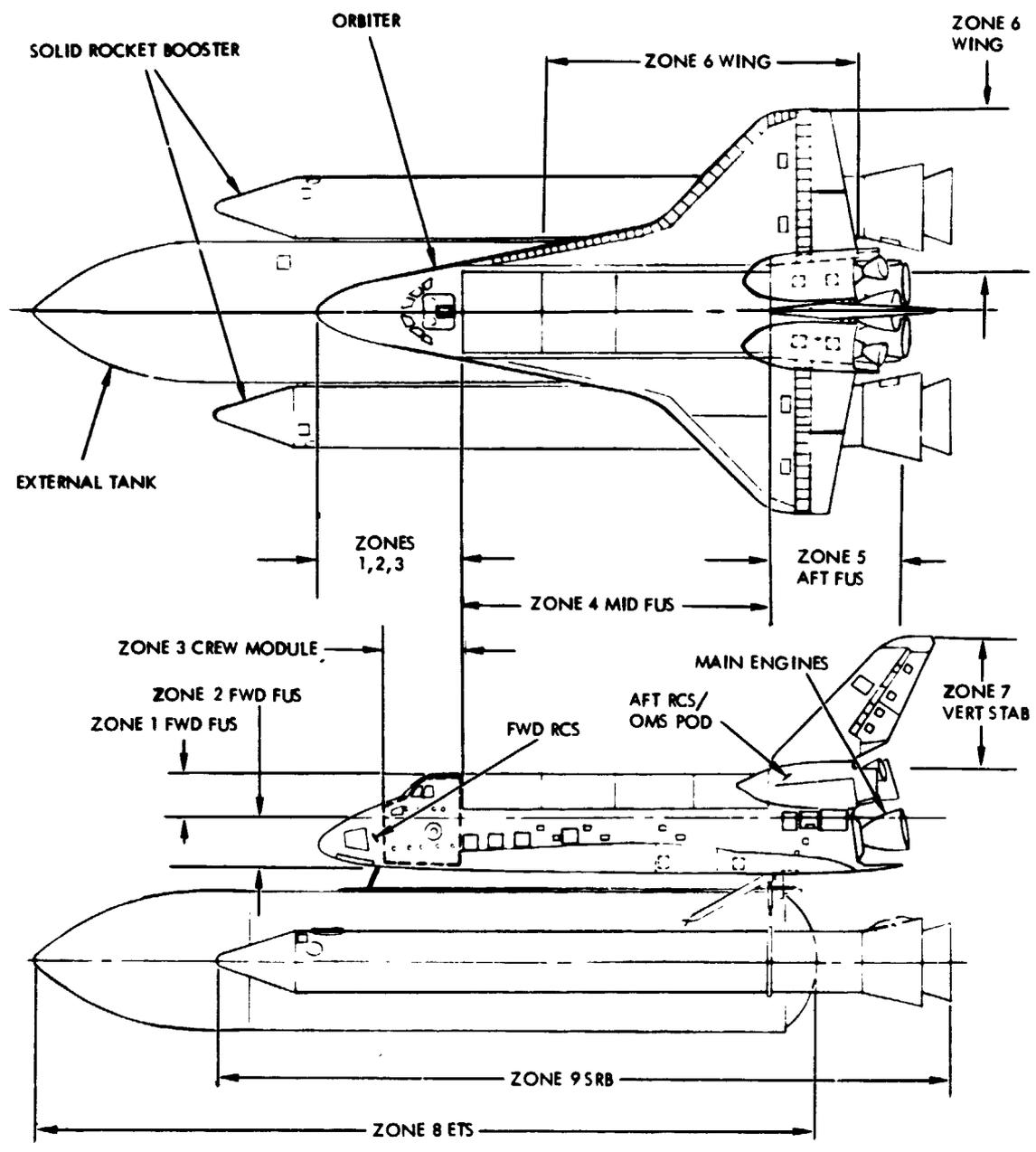


Figure 1-1. Shuttle Area Zone Breakdown

covered by low-temperature reusable surface insulation tiles (LRSI). The HRSI and LRSI are made of the same ceramic material and differ only in surface coating and thickness.

Figure 1-2 shows the major subassembly diagrams for the Orbiter. The Orbiter is characterized by a "floating" or cantilevered pressurized crew module, a 60' X 15' payload bay, double-delta planform wing, split elevons, split rudder and three main rocket engines. The vehicle also contains the orbital maneuvering system engines (OMS) and the reaction control system engines (RCS) which keep the thrust directed through the composite vehicle center of gravity from launch to orbit insertion.

1.2 Type of Construction

1.2.1 Forward Fuselage Structure and Crew Module

The forward fuselage structure extends from $X_{\circ} 238$ to $X_{\circ} 576$ and contains the fwd fuselage shell, crew module, nose landing gear, and the nose section. The nose section accommodates the NLG and RCS module. The $X_{\circ} 378$ bulkhead, which is the nose section aft boundary, has interface fittings for the NLG, the RCS module, and ET forward attach point and hoisting/jacking provisions. The $X_{\circ} 378$ bulkhead is constructed of flat sheet and formed sections riveted and bolted together. The forward fuselage carries the basic body bending loads and supports the crew module and reacts the NLG loads. The fwd fuselage shell is composed of 2024 aluminum alloy skin stringer panels, frames, and bulkheads. The crew module is a welded 2219 aluminum alloy assembly supported at four points on the $X_{\circ} 576$ bulkhead, but is not structurally connected to the forward fuselage. The frames are sheet-metal formed parts riveted to the skin stringer panels, spaced 20-24 inches apart.

1.2.1.1 NLG Wheel Well Structure and Doors - The NLG well assembly

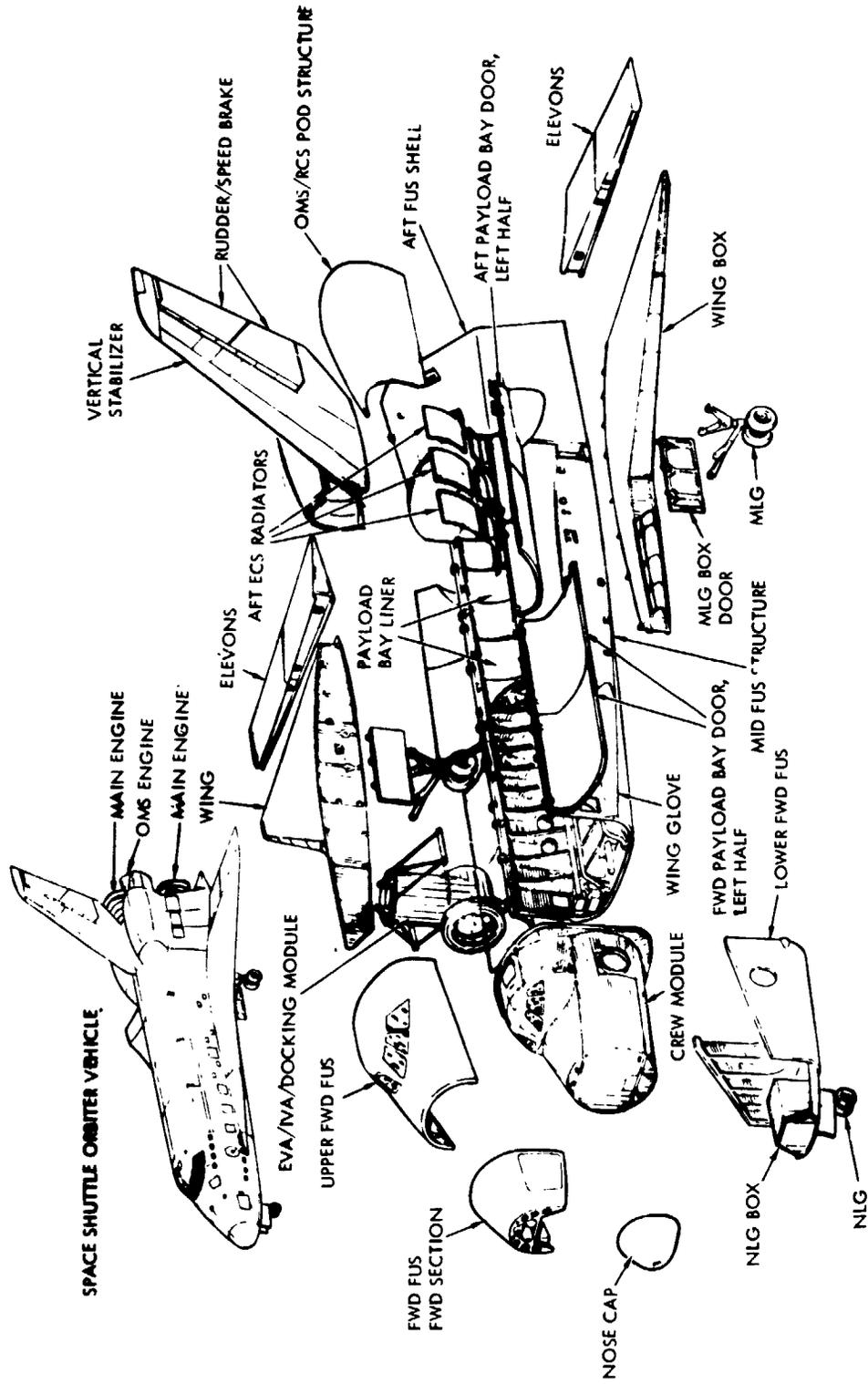


Figure 1-2. Major Subassembly Breakdown Diagram for Orbiter

consists of two support beams, upper closeout web, trunnion fittings, drag link and retract cylinder attachment fittings, and the landing gear door hinge fittings to which the doors are attached. The NLG is supported by two longitudinal beams which also support the LG doors.

1.2.1.2 Reaction Control System Module - The RCS tankage and thruster door are contained in a modular assembly in the upper nose section body structure. The module is attached to the X_0 378 bulkhead and the NLG box structure.

1.2.1.3 Aft Pressure Bulkhead at $X = 576$ - This bulkhead closes out the forward fuselage and provides structural support for the crew module, manipulator arms, and the cargo bay door closeout hinges.

1.2.1.4 Crew Module Structure - The crew module is a completely welded pressure vessel supported by the forward fuselage aft bulkhead. The crew module provides the habitable environment for the crew members and is pressurized to provide a shirt sleeve environment.

Walls - The conical and spherical skins are machined flat, fitted with stringers, formed to shape, and welded.

Bulkheads - The end bulkheads are machined in a waffle pattern in several pieces, welded into one assembly and reinforced with riveted beams.

Frames - The frames are formed and/or built-up rings mechanically fastened to exterior of the shell structure.

Windows - The window frames are five-axes machinings welded into the basic canopy shell.

Support Structure - The attachment to the fuselage consists of two rear trunnion mounts on the X_o 576 bulkhead which react vertical and longitudinal loads only. A shear tie link at X_o 576 and Z_o 283 supports cabin loads in the transverse ($\pm y$) direction only; a support at the X_o 378 bulkhead and Z_o 283 supports the cabin in the vertical (Z) direction. Twenty-one crew module-to-fuselage shell link assemblies stabilize the crew module within the forward fuselage by reacting transverse loads.

1.2.2 Mid-Fuselage Structure

The mid fuselage extends from X_o 576 to X_o 1307 and includes the structural box, payload bay doors, wing carry-through, forward portion of the wing glove, and the payload bay protective liner. The structure interfaces with the forward and aft fuselage structures, the wing, payload bay doors, main landing gears, payload manipulator, and ABPS pods if included.

The mid fuselage is the primary load carrying structure between the forward and aft sections of the fuselage and the wings.

1.2.2.1 **Payload Bay Doors** - The payload bay envelope is 15 feet (4.58m) in diameter and 60 feet (18.32m) long. The payload bay doors are hinged to fittings mounted on the mid fuselage sill longeron and are split along the upper centerline of the vehicle. The doors react transmitted fuselage torsional loads in addition to supporting their own flight and purge pressure loadings, but carry none of the primary structural loads. The doors provide structural support for the aft ECS radiators which are attached to the inner surface of the doors. When opened in orbit, the doors provide deployment for the ECS radiator panels. The payload bay door structure is a conventional riveted shell design made of 2024 aluminum alloy, using skin/frame/stringer construction.

1.2.2.2 **Payload Bay Liner** - The payload bay liner serves as a thermal con-

trol and contamination barrier between the payload and fuselage interior. The liner, designed for field installation and removal, extends over the full length and width of the mid fuselage.

1.2.2.3 Forward Wing Glove - The forward wing glove, extending from X_{\circ} 576 to X_{\circ} 807, is an extension of the basic wing that aerodynamically blends the wing to the mid fuselage section. It is constructed of 2024 aluminum alloy.

1.2.3 Aft Fuselage Structure

The main elements of the aft fuselage structure are the fwd bulkhead at X_{\circ} 1307, internal thrust structure, outer shell and floor structure, base heat shield, body flap, and all systems supporting secondary structure. The aft fuselage interfaces with the wing, the mid fuselage, the OMS/RCS pods, the external tank, and the vertical fin. The wing main spar and the structural attachments of the ET interface directly with the X_{\circ} 1307 bulkhead.

The aft fuselage structure provides a load path for the main engines to the ET interface points and to the mid fuselage longerons, a load path for the OMS engines to the mid fuselage as well as support for these systems, main wing spar continuity across X_{\circ} 1307 bulkhead and fuselage aft spar carry-through frame, vertical fin support, drag chute load reaction, body flap support structure, and secondary structural support of all installed systems.

1.2.3.1 X_{\circ} 1307 Bulkhead - This bulkhead is composed of three machined aluminum segments. The upper segment attaches to the vertical fin front spar to react moment and side shear. The bulkhead reacts side and vertical load components from the lower thrust members at the lower bulkhead corners where it attaches to the ET interface fittings which interface with the lower thrust members.

1.2.3.2 Thrust Structure - The thrust structure includes the main engine load

reaction truss structure, engine interface fittings, and the main engine actuator support structure. The thrust structure is composed mainly of machined, diffusion-bonded titanium truss members, reinforced by boron/epoxy laminations. The thrust structure upper sections support the upper main engine while the lower sections support the two lower main engines. The actuator support portion of the thrust structure includes not only the upper and lower truss members but shear webs and beams that extend between these sections for actuator side load reaction capability. These elements are also titanium with boron/epoxy reinforcement in selected areas.

1.2.3.3 Outer Shell and Floor Structure - The outer shell and floor structure of the aft fuselage are of stiffened aluminum construction with intermediate frame stabilization. The frames are of aluminum construction including the fin support frame which attaches to the main spar of the vertical fin and reacts fin moment and shear. The outer shell upper surface attaches to each side of the fin to react drag and torsion loadings. The outer shell includes structural interface attachments to the OMS/RCS pod. Various penetrations are provided in the shell for access to internal structure. The floor includes penetrations for the external tank propellant lines and attachment points to the external tank.

1.2.3.4 Base Heat Shield - The base heat shield closes out the base area of the aft fuselage and consists of aluminum sandwich flat panels covered with RSI tiles and bulge-stiffened inconel hot structure sections. The bulged sections are removable. The heat shield limits the endothermic heat flow, resists the pressure differential encountered as the vehicle vents during ascent and withstands the extreme acoustic environment when the engines are firing.

1.2.3.5 Body Flap - The body flap protects the main engine skirts and provides a movable control surface for vehicle trim during entry. Rotary actuators are used to control flap movement. The structure basically consists of RSI-protected aluminum honeycomb on a spar/rib assembly.

1.2.3.6 Secondary Support Structure - This structure supports the extensive systems components in the aft fuselage. The secondary structure consists mainly of aluminum brackets, built-up webs, truss members, and machined fittings. Some of these components may be affected by vibro-acoustic loads during liftoff and ascent.

1.2.3.7 OMS/RCS Pod Structure - The OMS/RCS Pod is an RSI protected 2024 aluminum alloy shell of sheet/stringer/frame construction. The OMS tank is supported on an aft shelf assembly supported by the OMS shell and webs. The OMS engine is supported from the OMS tank aft support shelf assembly.

1.2.4 Wing Structure

The double-delta wing provides conventional aerodynamic lift and control for the Orbiter vehicle during launch abort, re-entry, cross-range flight and landing. The wing also provides one-half the main landing gear support.

The wing contains a forward wing box of conventional multi-rib and stiffened skin design, extending from $X_{O} = 1040$ aft to $X_{O} = 807$ forward. The forward box interfaces with the mid fuselage wing glove at the forward point. This substructure incorporates attachment provisions for the leading edge thermal protection system and associated insulation and provisions for mechanical attachment to the mid fuselage and main wing box.

1.2.4.1 Main Wing Box - The main wing box structure is a conventional multi-spar/rib and stiffened skin design which extends from $X_{O} = 1387$ to $X_{O} = 1040$. This substructure contains the main landing gear storage compartment with associated subsystems, provides support for the elevons and has provisions for externally mounting the airbreathing engine system. The main wing box structure transfers wing aerodynamic loads, including elevon flight control loads, to the fuselage and reacts a portion of the main landing gear loads. The box is enclosed fore and aft by the main front spar and the main rear spar which are built up from machined caps riveted

to corrugated webs. The ribs are built-up from square tube trusses, except those that carry elevon or MLG loads which are constructed similarly to the spars. The wing structure is attached to the mid fuselage at 9 clevis attach points on each wing. The leading edge incorporates attachments for the leading edge RSI and associated insulation.

1.2.4.2 Elevons - The elevons provide flight control for the Orbiter vehicle during abort, re-entry, cruise flight, and during conventional horizontal take-off and landing. Hinged along X_0 1387, they extend from the fuselage to the wing tip along the wing trailing edge. The elevons are divided into two segments, each supported by three hinges. The elevons are a multi-rib stiffened skin design made of aluminum bonded honeycomb construction.

1.2.5 Vertical Stabilizer Structure

The vertical tail is an aerodynamic surface that is attached to and extends above the orbiter aft fuselage. It provides means of vehicle aerodynamic stability and control during re-entry, cruise flight and landing.

1.2.5.1 Structural Fin - The structural fin consists of conventional stiffened skin structure with ribs and two spars, making a torque box for the primary loads. The skin panels are stiffened by hat sections riveted to the skin. The spars are machined plate with integral stiffeners and the ribs are square tube trusses except at the rudder actuators where they have a corrugated web. The primary attachment of the vertical stabilizer to the body is made at the front and rear spar through machined fittings attached to the main thrust structure.

1.2.5.2 Rudder/Speed-Brakes - The rudder consists of two spanwise sections which are attached to the stabilizer at the 60% chord line. The rudder is split along the chord plane to act as a speed brake. The rudder/speed brake skin panels are bonded aluminum honeycomb with ribs and spars which carry the primary loads.

1.2.6 Thermal Protection System (TPS)

The TPS consists of nonmetallic materials applied externally to the Orbiter's primary structural shell to maintain the airframe outer skin to within acceptable temperature limits, below 350°F. The TPS can be divided into four major categories:

1. Low temperature reusable surface insulation (LRSI) on Orbiter upper surfaces where radiation equilibrium surface temperatures below 1200°F will be experienced.
2. High temperature reusable surface insulation (HRSI) on airframe surfaces where radiation equilibrium surface temperatures between 1200°F and 2300°F will be experienced.
3. Leading edge, nose cap, chine and structural attachments along with internal insulation exposed to temperatures greater than 2300°F.
4. Thermal seals for the rudder, speed brake, elevon, cargo bay door, hinge openings and the outer thermal window panes and other structure penetrations.

The nonmetallic LRSI and HRSI tiles are adhesively bonded to the airframe surfaces. A strain isolation pad is used as an intermediate layer between the LRSI and the airframe. The leading edge TPS, constructed of carbon-carbon aerodynamically-shaped panels, uses mechanical attachment devices for mating to the airframe.

The TPS materials are coated with a thin waterproof, semi-permeable emissivity coating for radiative heat control and water barrier. This coating must be of high integrity for each mission. The major difference between HRSI and LRSI is the type of emissivity coating used to achieve the proper radiation temperature control. The TPS materials vary in thickness and may be flat, contoured or wedge-shaped.

The safe-life designed TPS is subject to disbonds, cracks, delaminations, impact damage, coating spalling and microcracks. The integrity of the TPS must be

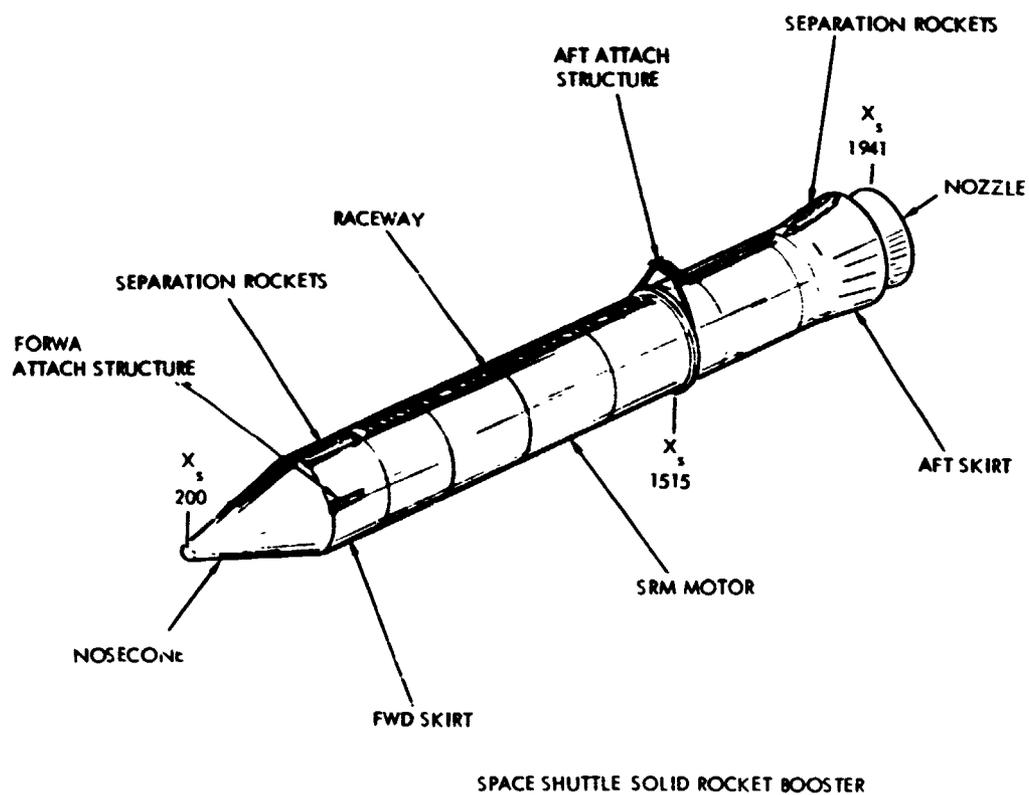


Figure 1-3. Assembly Breakdown Diagram for Solid Rocket Booster

verified by the use of NDT after and/or prior to each flight as follows:

Post flight NDE - damage assessment

Pre flight NDE - integrity of reinstalled, serviced, or personnel-exposed TPS

These materials will affect access to structural inspection and, in some areas, must be removed to permit the use of backup or verification NDT techniques.

1.2.7 Solid Rocket Booster (SRB) Structure

Each Shuttle vehicle will use two reusable SRB's to fire simultaneously with the Orbiter main engines during liftoff and ascent. The SRB's will be mechanically attached to the orbiter and external LO_2 - LH_2 propellant tank, with quick release capability for burnout jettison and abort. A structural diagram of the SRB vehicle is shown in Figure 1-3.

The SRB main structural element is the 142-inch (3.61m) diameter cylindrical motor case comprised of segments mechanically jointed to obtain a length of 1300 inches (~33m) dome-to-dome. Overall length of the SRB is 1741 inches (44.22m). The segments are fabricated from D6-AC steel to a wall thickness of 1/2-inch (1.27mm). Segment splicing is implemented by a tongue-and-groove joint held together with shear pins. A closure dome is provided at the forward end of the motor case and a dome with nozzle closes out the aft end. The assembly contains provisions for attachment and thrust transfer to the ET. The SRB's are recoverable for refurbishment and reuse on later vehicles.

1.2.8 External Propellant Tank (ET)

The ET is a large monocoque cylindrical structure which houses two main liquid oxygen and liquid hydrogen tank subassemblies used to store and provide propellents to the Orbiter's three main gimballed engines. The LO_2 tank is housed at the forward end and is shaped to provide an aerodynamic conical nose contour. Overall length of the ET is 1989 inches (50.52m) and its maximum diameter is 324 inches (8.23m).

The LH_2 and LO_2 tanks are separated by a skirt. The tanks are welded

2219-T81 aluminum alloy shells of revolution with local stiffening employed only in regions of concentrated longitudinal loading which is introduced by the attachments of the Orbiter or SRB's.

The ET continues to propel the Orbiter into earth orbit after the SRB's have been ejected and is also jettisoned when the desired orbit is achieved. It is not recoverable; therefore, refurbishment is not required. However, preflight verification of the intervehicular attachment integrity is required.

1.2.9 Surface Finish Systems - Orbiter

The aluminum and steel fittings, frames, skin panels, bulkheads and other components have a specification surface treatment and finish to protect the materials from damage due to environmental factors. The general finish systems are as follows:

Structure interior - zinc chromate epoxy primer plus one coat of Supercorapon 515-700 paint.

Structure exterior - zinc chromate epoxy primer plus two coats of Supercorapon 515-700 paint.

Cabin interior - low outgassing polyurethane enamel, De Soto Velvet Coat or similar.

Landing Gear - abrasion-resistant polyurethane enamel system.

1.3 Inspection Access Provisions

Internal and external access provisions on the Orbiter vehicle are shown in Figure 1-4. To obtain access to parts for inspection, remove access doors and panels as necessary. In addition, inspection of some areas will require removal of thermal insulation, thermal seals, fairings and/or adjacent equipment. For the purpose of locating major structural features on the Shuttle vehicles and locating structure/components to be inspected, a simplified station diagram is shown in Figure 1-5.

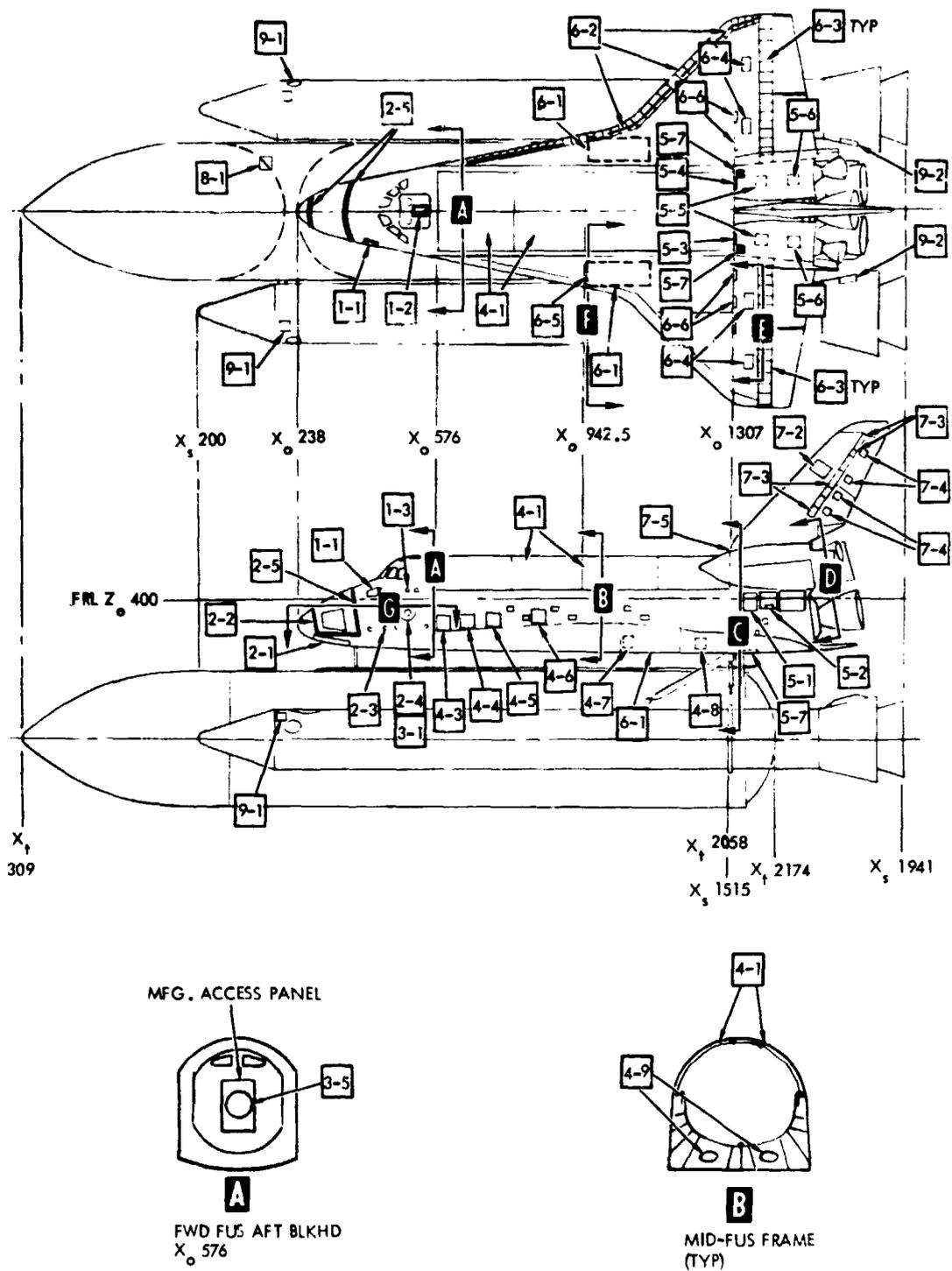
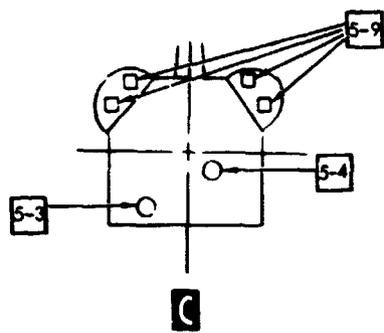
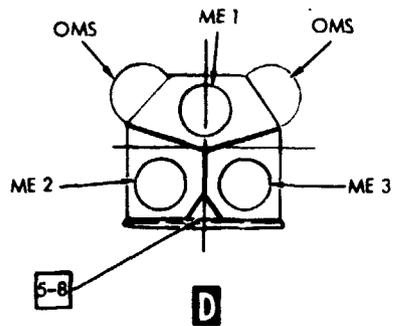


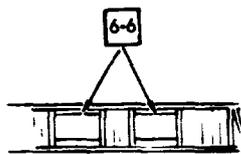
Figure 1-4. Access Provisions for Space Shuttle (Sheet 1 of 4)



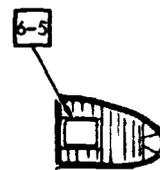
C
X_o 1307 BLKHD
LOOKING FWD



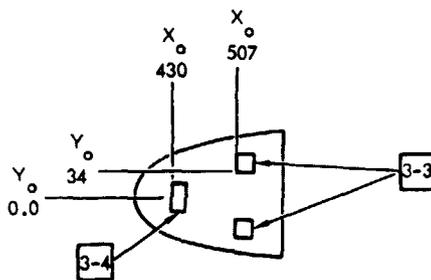
D
AFT HEAT SHIELD
LOOKING FWD



E
WING REAR BEAM
X_w 1307



F
MLG WHEEL BOX
FWD SPAR
LOOKING AFT
X_w 1040



G
FLIGHT DECK FLOOR
LOOKING DOWN

Figure 1-4. Access Provisions for Space Shuttle (Sheet 2 of 4)

KEY: (TYPE OF ACCESS)

H - Hatch, Quick Opening
D - Door, Quick Opening
P - Panel, Multiple Fastener
V - Opening, Void

	<u>Designation</u>	<u>Location</u>	<u>Type</u>
1-1	Startracker Access	Zone 1	Door, D
1-2	Emergency Hatch	Zone 1	Door, H
1-3	Cabin/Fus Link (9 ea)	Zone 1	Panel, P
2-1	NLG Door	Zone 2	Door, D
2-2	RCS Door	Zone 2	Door, D
2-3	Cabin/Fus Link (12 ea)	Zone 2	Panel, P
2-4	Crew Hatch	Zone 2	Door, H
3-1	Crew Cabin Hatch	Zone 3	Door, H
3-2	Primary Interdeck Access	Zone 3	Door, D
3-3	Secondary Interdeck Access	Zone 3	Door, D
3-4	Flight Deck Fwd Access	Zone 3	Panel, D
3-5	Airlock Cargo Bay Hatch	Zone 3	Door, H
4-1	Cargo Bay Door, Fwd	Zone 4	Door, D
4-2	Cargo Bay Door, Aft	Zone 4	Door, D
4-3	ECCLS Sublimator Access LH	Zone 4	Panel, P
4-4	ECCLS Sublimator Access RH	Zone 4	Panel, P
4-5	ECCLS Fuel Cell Access	Zone 4	Panel, P
4-6	Cargo Servicing Panel	Zone 4	Panel, P
4-7	MLG Well/Fus Access	Zone 4	Opening, V
4-8	Wing/Fus Aft Access	Zone 4	Opening, V
4-9	Frame Crawlspace Access, Typ	Zone 4	Opening, V
5-1	Aft Fus Access (2 ea)	Zone 5	Door, D
5-2	APU Access	Zone 5	Panel, P
5-3	Mid Fus Underfloor Access	Zone 5	Opening, V
5-4	Cargo Bay Access	Zone 5	Opening, V
5-5	OMS Equip Access	Zone 5	Panel, P
5-6	OMS Eng Access	Zone 5	Panel, P
5-7	ET Struct Attach Access	Zone 5	Panel, P
5-8	Aft Heat Shield Access	Zone 5	Panel, D
5-9	OMS/RCS Pod Access	Zone 5	Panel, P

Figure 1-4. Access Provisions for Space Shuttle (Sheet 3 of 4)

KEY: (TYPE OF ACCESS)

H - Hatch, Quick Opening
D - Door, Quick Opening
P - Panel, Multiple Fastener
V - Opening, Void

	<u>Designation</u>	<u>Location</u>	<u>Type</u>
6-1	MLG Doors	Zone 6	Door, D
6-2	Wing Leading Edge Interior Access Panels	Zone 6	Panel, P
6-3	Wing Trailing Edge/Elevon Hinge Access Panels, 30	Zone 6	Panel, P
6-4	Elevon Actuator Access Panels, 4	Zone 6	Panel, P
6-5	Whole Body Access Opening, X _o 1040 Wing Spar, Wing Interior	Zone 6	Opening, V
6-6	Whole Body Access Openings, X _o 1307 Rear Spar, Wing Interior	Zone 6	Opening, V
7-1	Drag Chute Access Doors	Zone 7	Door, D
7-2	Rudder Actuator Access	Zone 7	Panel, P
7-3	Rudder Hinge Access	Zone 7	Panel, P
7-4	Rudder, Hinge Access	Zone 7	Panel, P
7-5	Vert Stab Leading Edge/Fus Attach Access	Zone 7	Fairing, P
8-1	External Tank Maintn. Access	Inter-tank Area	Panel, P
9-1	SRB Nose Cone Exten. Access	Nose Cone	Panel, P
9-2	SRB Aft Separation Rocket Access	Aft Skirt	Panel, P

Figure 1-4. Access Provisions for Space Shuttle (Sheet 4 of 4)

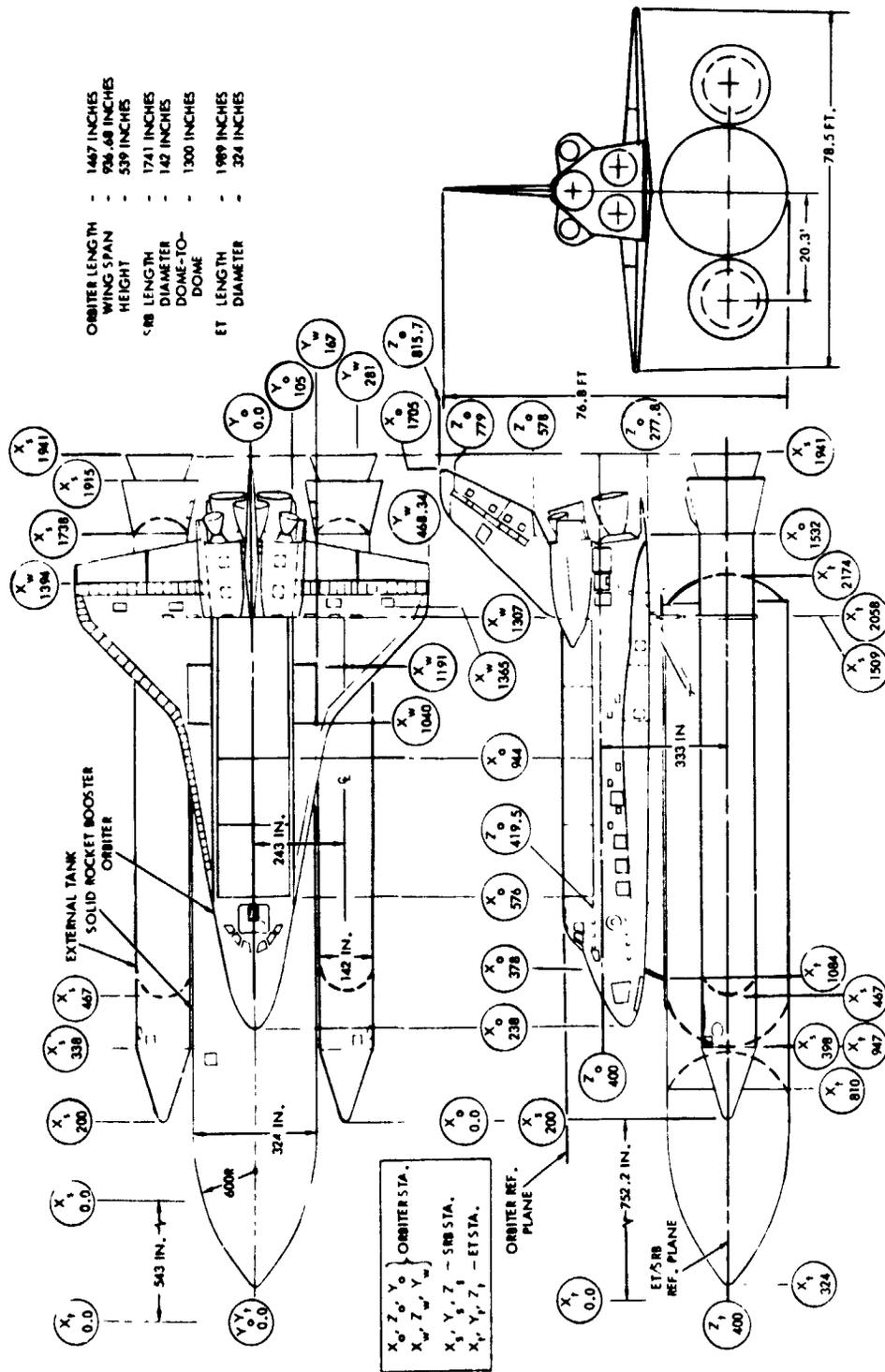


Figure 1-5. Station Diagram for Space Shuttle Vehicles

1.4 NDE Symbols

Each illustration of the test involved employs the use of symbols representing the NDT methods to be used. These symbols are keyed on the part illustrations to indicate where the inspection is to be directed. Figures 1-6a and 1-6b present the NDE symbols used.

<p>PENETRANT</p>  <p>PENETRANT NDE SYMBOL</p>	<p>MAGNETIC</p>  <p>MAGNETIC PARTICLE NDE SYMBOL</p> <p>MAGNETIC FIELD DIRECTION →</p>	<p>OPTICAL</p>  <p>OPTICAL NDE SYMBOL</p>
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RADIOGRAPHY		
<p>X-RAY</p> <p>① FILM NUMBER</p>  <p>RADIOGRAPHIC X-RAY TUBE NDE SYMBOL TARGET</p> <p>E-1 EXPOSURE NUMBER</p>	<p>GAMMA RAY</p>  <p>GAMMA-RAY NDE SYMBOL</p>	<p>NEUTRON RAY</p>  <p>NEUTRON NDE SYMBOL</p>

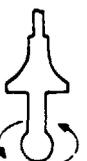
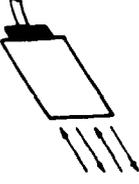
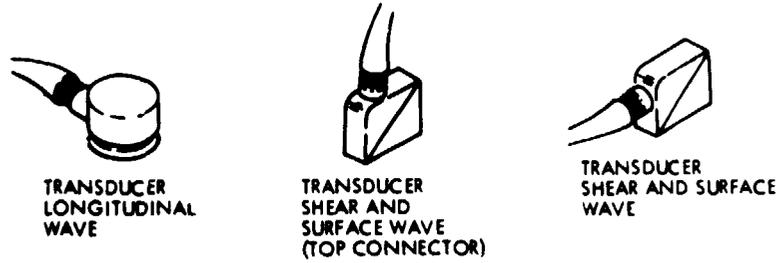
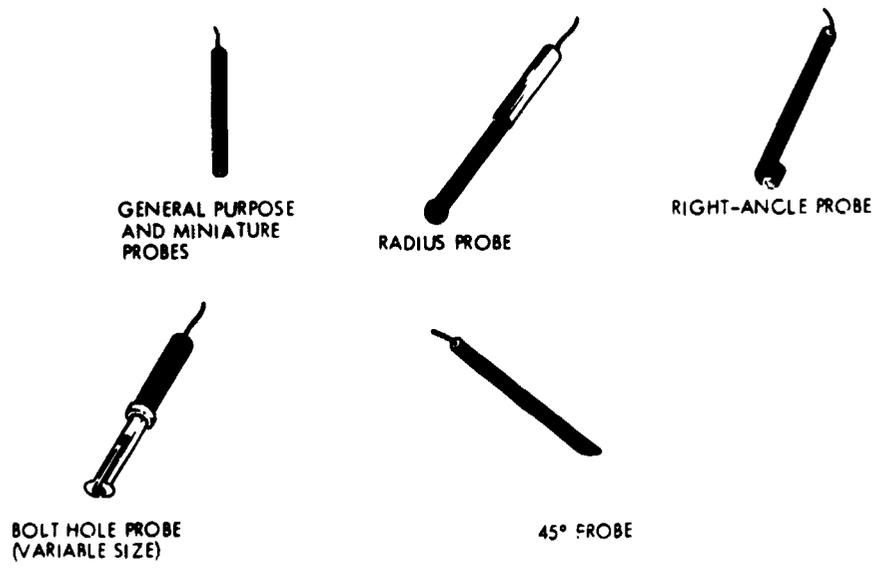
<p>EDDY CURRENT</p>  <p>EDDY CURRENT NDE SYMBOL</p>	<p>ULTRASONIC</p>  <p>ULTRASONIC NDE SYMBOL</p>	<p>SONIC</p>  <p>SONIC NDE SYMBOL</p>
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Figure 1-6A. Nondestructive Testing Method Symbols



Ultrasonic Transducer Symbols



Eddy Current Probe Symbols

Figure 1-6B. Ultrasonic Transducer and Eddy Current Probe NDE Illustrations

1.5 Nondestructive Evaluation Methods

The basic theory and principles of NDE methods are contained in various references such as the following:

- 1) NASA SP-5113, Nondestructive Testing (Survey), 1973
- 2) USAF T.O. 33B-1-1, Nondestructive Inspection Methods
- 3) AMCP 782-10 (AD 728162), Quality Assurance: Guidance to Nondestructive Testing Techniques, April 1970
- 4) R. C. McMasters, Ed. Nondestructive Testing Handbook, 2 Vols.
- 5) W. J. McGonnagle, Nondestructive Testing, 1969, 2nd Ed.
- 6) NASA CR-61231, Radiographic Testing Classroom Training Handbook, 1967
- 7) NASA: CR-61212, Vol. I, Radiography: Origin and Nature of Radiation, 1967 (N68-28784)
CR-61213, Vol. II, Radiography: Radiation Safety, 1967 (N68-28785)
CR-61214, Vol. III, Radiography: Radiographic Equipment, 1967 (N68-28786)
CR-61215, Vol. IV, Radiography: Making a Radiograph, 1967 (N68-28787)
CR-61216, Vol. V, Radiography: Film Handling and Processing, 1967 (N68-28788)
- 8) NASA CR-61229, Liquid Penetrant Testing: Classroom Training Handbook, 1968
- 9) NASA CR-61228, Ultrasonic Testing: Classroom Training Handbook, 1965
- 10) NASA: CR-61209, Ultrasonics, Vol. I, Basic Principles, (N68-28781), 1967
CR-61210, Ultrasonics, Vol. II, Equipment, (N68-28782), 1967
CR-61211, Ultrasonics, Vol. III, Applications, (N68-28783), 1967
- 11) NASA CR-61230, Eddy Current Testing: Classroom Training Handbook, 1967

- 12) Standard, M. W., et al., Development of Microwave NDT Inspection Techniques for Large Solid Propellant Rocket Motors, (NAS7-544, Aerojet-General Corp., Sacramento), June 1969
- 13) NASA CR-107670, Microwave Inspection Applications Guide, 1969
- 14) NASA CR-61227, Magnetic Particle Testing: Classroom Training Manual, (N68-28789) 1967

For qualification and certification of nondestructive testing personnel, it is recommended that the ASNT documents Recommended Practice No. SNT-TC-1A and/or MIL-STD-410D (Proposed) Nondestructive Testing Personnel Qualification and Certification be used.

1.5.1 Optical Method

1.5.1.1 Description - Optical inspection is defined as the viewing of a critical area with the aid of a magnifying glass, light source, borescope, or other optical tool. Routine visual inspections such as walk-around and naked eye monitoring are not pertinent to descriptions in this manual, although visual scrutiny of any critical area/component subject to evaluation under terms of this manual is highly encouraged.

The primary objective of optical NDE techniques in this manual is to prescribe a means to inspect inaccessible fail-safe structures for large cracks or failed members. Other uses can include inspection of inaccessible areas for failed brackets, loose components, corrosion, leaks or spilled fluid. The primary purpose can be accomplished by insertion of borescopes into structural access ports or the use of permanently installed borescopes aimed at specific critical areas. Diagrams of various types of commercially available borescopes are shown in Figure 1-7. The direction of view and field of views that are available for various borescopes are given in Figure 1-8.

1.5.1.2 Visual/Optical Devices -

A. Borescopes (Refer to Figures 1-7 and 1-8.)

- o A borescope is a precise optical instrument with built-in illumination. It can be used for visual check of internal areas and for deep holes.
- o Borescopes are available in numerous models from 0.10-inch (2.54mm) diameter and a few inches in length to 0.75-inch (19.05mm) diameter and several feet in length. They are generally provided with fixed diameters and working lengths, with optical systems designed to provide direct, right angle, retrospective, and oblique vision.
- o Fiber Optics - Flexible "light pipes," consisting of a bundle of fine optical fibers, are readily adaptable to remote viewing of inaccessible

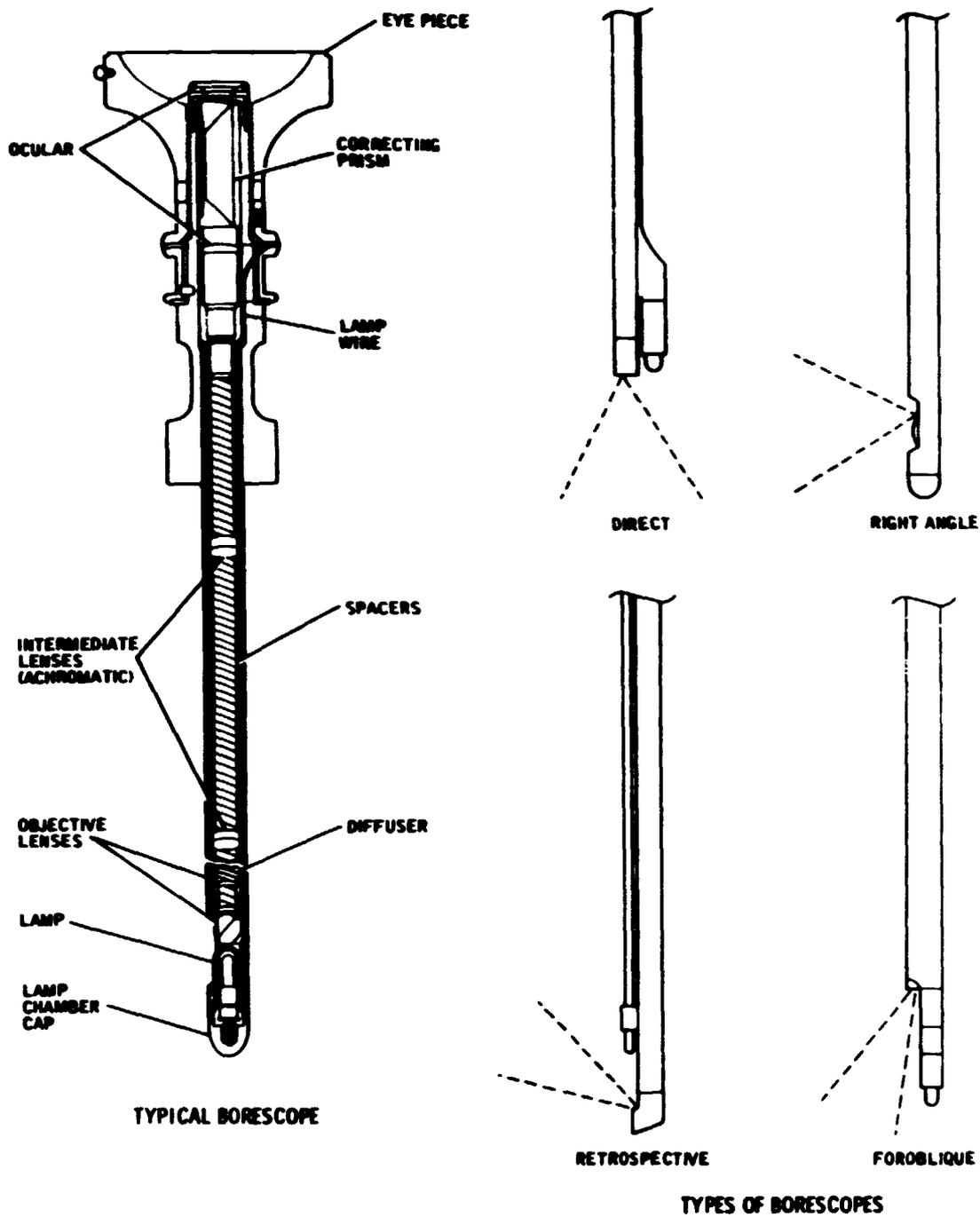
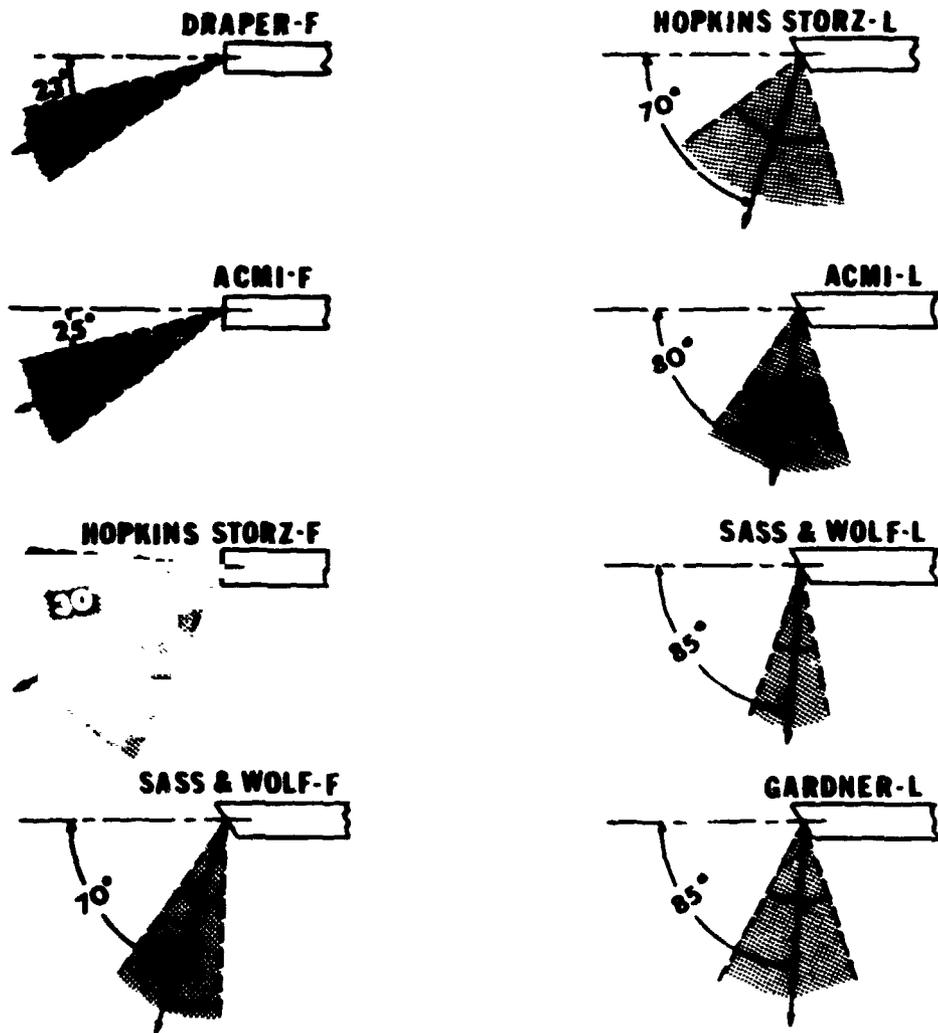


Figure 1 7. Illustrations of Some Types of Optical Borescopes



	LATERAL	FOROBLIQUE	FORWARD
ACMI	52°	30°	--
Sass and Wolf	30	35	--
Gardner	47	47	--
Draper	--	--	23
Hopkins-Storz	70	70	--

Figure 1-8. Direction and Field of View for Several Types of Borescopes

structure or components and are easily bent around and through the structure. These devices are desirable for permanent or built-in viewing installations in which fail-safe designed structures can be inspected at any time for large cracks or fracture. Loose components, fluid leaks and other defective conditions can be detected. They can be used for the observation of a mechanical operation such as landing gear deployment, remote door closure, and the like. The fiber bundles are available in various lengths and diameters. When long fiber lengths are used, the bundle diameter should be increased to compensate for line attenuation. Permanently installed fiber bundles may, in time, be degraded by temperature extremes and man-made or natural environments to which the Orbiter is subjected.

- B. Viewing Instrumentation. In addition to cameras, both still and motion, for permanently recording the images viewed through optical devices, other systems provide amplified real-time viewing of the image. A closed-circuit television system employing a vidicon camera will provide instant viewing of the borescope image on a full-scale television monitor screen. The EV image is a 40X or greater magnification of the 1/4-inch (6.35mm) eyepiece image. The TV image can, in addition, be stored on video tape for later viewing. Suitable vidicon systems are produced by Unitron, Sony, RCA, and RAM.

1.5.1.3 Optical Procedures for Borescopes

- A. A knowledge of the type of defects that may develop in Shuttle structure that are observable visually and most probable sites for such defects is a prerequisite for employing optical NDE methods.
- B. Select the appropriate borescope and examine it to determine that the eyepiece and objective lens are clean and "frost" free. Check operation of the light to assure that the batteries (if applicable) are sufficiently strong for high illumination. If still or moving cameras are to be used to

obtain permanent photographic records of the inspection area through the borescope, check the camera lens for cleanliness and set the focus, f-stop and length of exposure; assure adequate films.

- C. Insert the borescope into the access or port holes and direct to the inspection area. Observe the critical area through the borescope and ascertain that sufficient illumination, depth of field, and field of view are present to completely inspect the area. If a permanently installed borescope is used, it is only necessary to remove the protective end cap and connect the illumination source to prepare the instrument for use.

NOTE: The inspection area must be free of
dirt, fluids, sealant, insulation and
the like which can conceal defects.

- D. Carefully examine the area. Record all discrepancies for later evaluation. Take photographs or motion film through the borescope if desired.

TABLE 1. OPTICAL TEST INSTRUMENTS

Test Equipment	Manufacturer and Supplier	Trade Name
Flexible Fiber Optic Inspection Instrument	American Optical Company Fiber Optics Dept. 14 Mechanic Southbridge, Massachusetts	Fiberscope
Optical Magnifier Comparators, and Fiber Flexiscope	Bausch and Lomb Scientific Instrument Div. 1434 West 11th Street Los Angeles, California 90015	Bausch and Lomb
Borescope	L. E. Baxter, Ltd. 1229 Queensway Toronto, Ontario, Canada	Ellispection
Flexible and Rigid Inspectroscopes	Eder Instrument Co., Inc. 2293 North Clybourn Street Chicago, Illinois 60614	Ederscope
Aircraft Inspection Borescopes	Lenox Instrument Company 111 East Luray Street Philadelphia, Pennsylvania 19120	Lenox
Borescopes	National Electric Instrument Division Englehard Hanovia Inc. 92-21 Corona Avenue Elmhurst, Long Island, New York 11373	National
Borescope and Endoscope Photography	National Statham Inc. 91-21 Corona Avenue Elmhurst, Long Island, New York 11373	Nikon
Flexible Borescope	Olympus Corp. of America Special Products Div. 2 Nevada Drive New Hyde Park, N. Y. 11090	Olympus IF
Optical Instrument	Quality Control Company 3301 Beverly Boulevard Los Angeles, California 90004	Look-See-Kit

1.5.2 Penetrant Method

1.5.2.1 Description - In aerospace penetrant inspection a high-mobility liquid fluorescent penetrant is applied to the surface of the part. The liquid penetrates surface defects such as cracks, pores, laps, and folds. Excess penetrant is removed from the surface, and a suitable developer is applied to draw the penetrant from the surface defects. Visual indications are obtained by fluorescence of the penetrant under the influence of "black light" in order to increase the visible contrast between a discontinuity and its background. This method is effective for detecting surface defects in forgings, casting, extrusions, formed sections, webs, and skins of nonferrous or ferrous material. The penetrant method of inspection requires that the surface in the inspection area be thoroughly clean and free of paint. Penetrants should not be applied to faying surfaces and joints.

The penetrant method can be applied widely to inspection of Space Shuttle structure. It inherently has high reliability, and is one of the most reliable for cracks in the 0.050 inch to 0.150 inch (1.27mm to 3.81mm) size range.

NOTE: Due to the large number of titanium parts and fasteners used on the Space Shuttle vehicle, only sulphur-free and chlorine-free ion penetrant inspection materials must be used. Penetrants which contain sulphur or chlorine may cause stress-corrosion in titanium parts.

Two penetrant procedures are given in Figures 1-9 and 1-10. The procedure given in Figure 1-9 for a portable system is to be used on the spacecraft. The procedure given in Figure 1-10 is for stationary penetrant equipment, and parts must be removed from the airplane to be applicable for this process. Data in Figures 1-9 and 1-10 were developed using Magnaflux Corporation penetrant materials. These materials and any equivalent materials must conform to Specification MIL-I-25135. Equivalent materials must exhibit equal sensitivity for crack detection and must be free of chlorine and sulphur ions.

Instructions

- a. Preparation of Part: Refer to specific procedure for preparation of part.
- b. Pre-Cleaning: After the finish has been removed, pre-clean the area to be inspected with the solvent cleaner and wipe dry with a clean dry cloth. On titanium parts, use a non-chlorinated solvent or an alkaline cleaning process.
- c. Penetrant Application: Apply penetrant either by brushing or spraying. In a confined area apply with a brush to prevent an over-spray in the area to be inspected. In temperature below 60°(F) pre-heat the area to be inspected before applying the penetrant. The surface area may be heated with the black light or with hot air heaters.
- d. Penetrant Removal: Use the solvent cleaner and a clean lint-free cloth to remove the excess penetrant. Check the area to be inspected with the black light to assure that the excess penetrant has been removed prior to applying the developer.
- e. Developer: Spray a light film of developer over the area to be inspected.

TYPE I, GROUP VII, SOLVENT - REMOVABLE FLUORESCENT DYE PENETRANT

MATERIAL	FORM	TYPE OF DISCONTINUITY	MINUTES PREPARATION TIME	PENETRANT REMOVAL TIME	MINUTES DEVELOPER DWELL TIME
All	All	Cracks	30 Minimum	Optimum time is the minimum time required to remove the surplus penetrant.	15

FIGURE 1-9. PENETRANT PROCEDURE - PORTABLE OR FIELD APPLICATION

Instructions

- a. Preparation of Part: Refer to specific procedure for preparation of part.
- b. Pre-Cleaning: Vapor degreasing is the preferred method of pre-cleaning. On titanium parts use a non-chlorinated solvent or an alkaline cleaning process.
- c. Penetrant Application: The penetrant may be applied by brushing, spraying, or dipping.
- d. Emulsifier Application: The emulsifier may be applied by brushing, dipping or spraying. The preferred method of application is by dipping the part in the emulsifier. The emulsifier and excess penetrant may be removed by water wash using a low pressure (30-40 psi), 2.109×10^3 to 2.812×10^3 g/cm² water spray.
- e. Developer Application: The preferred method of applying the aqueous wet developer is by dipping the part in a well-agitated developer solution.
- f. Drying Operation: The parts should be dried in a circulating air dryer with temperature range from 140° to 180°F. The time in the dryer should not exceed the time necessary to completely dry the surface of the parts.

TYPE I, GROUP V OR VI POST EMULSIFIABLE TYPE PENETRANT
(Use only sulphur-free and chlorine-free ion materials.)

MATERIAL	FORM	TYPE OF DISCONTINUITY	MINUTES PENETRATION TIME	TIME EMULSIFIER	DEVELOPER
All	All	Cracks	30 Minimum	3-5 Min	Minimum 15 minutes after drying operation

FIGURE 1-10. PENETRANT PROCEDURE - STATIONARY

1.5.2.2 Penetrant Types, Methods and Groups -

- A. Penetrant Types. Penetrants are classified under Specification MIL-I-25135 into Type I and Type II. Type I penetrants use dyes that fluoresce in the presence of ultraviolet light, thus making them visible. Type II penetrants use dyes which are visible in ordinary light sources.

- B. Penetrant Methods. The penetrant methods are further classified as Method A, Method B, and Method C, according to the method of application.
 - 1. Method A penetrants use dyes containing water-washable emulsifier and a dry, wet, or nonaqueous wet developer. These are usually the lowest sensitivity penetrant systems.

 - 2. Method B penetrants use dyes, an emulsifier, and a dry, wet or non-aqueous wet developer. The emulsifier is applied over the penetrant to make it water washable. These penetrant systems have intermediate levels of sensitivity.

 - 3. Method C penetrants use solvent-removable dyes, a penetrant remover solvent), and a dry, wet, or nonaqueous wet developer. These are the highest sensitivity penetrant systems.

- C. The penetrant materials are further divided into groups. Groups I through VII are shown in Table 2. Commercial penetrant supplies belonging to Type I, Method C, Group VII materials are given in Table 3.

- D. Penetrant Materials and Suppliers. Table 3 provides a listing of some Type I, Method C, Group VII materials.

- E. Developers
 - 1. Developers are of three types: dry, wet, and nonaqueous wet. Developers cause minute quantities of penetrant to emerge to the surface from a discontinuity and retains them. The developer forms a light

TABLE 2. PENETRANT GROUPS

GROUPS	DESCRIPTION	
I	Visible, Solvent-Removed	↓ Sensitivity Increases ↓
II	Visible, Post-Emulsifiable	
III	Visible, Self-Emulsified	
IV	Fluorescent, Self-Emulsified	
V	Fluorescent, Post-Emulsifiable	
VI	Fluorescent, Post-Emulsifiable	
VII	Fluorescent, Solvent-Removed	

TABLE 3. TYPE I, METHOD C, GROUP VII
PENETRANT INSPECTION MATERIALS

NAME	NUMBER	MANUFACTURER
Penetrant	ZL-22	Magnaflux Corp. 7200 W. Lawrence Ave. Chicago, Illinois
Remover	ZC-7	
Developer	ZP-9	
Penetrant	P-149	Shannon Luminous Materials Company Tracer-Tech Division 7356 Santa Monica Blvd. Los Angeles, Calif.
Remover	K-410A	
Developer	D-495A	
Penetrant	Fl-22	Testing Systems, Inc. 2826 Mt. Carmel Ave. Glenside, Pa. 19038
Remover	FC-44	
Developer	FD	
Penetrant	P-40	Turco Products, Inc. 2600 South Main Street Wilmington, Calif.
Remover	R	
Developer	NAD	
	DD	
	WD	
Penetrant	FP-30	Sherwin, Inc. 5007 E. Washington Blvd. Los Angeles, Calif.
Remover	DR-60	
Developer	D-100	

background thus increasing the contrast between the background and penetrant indication. The recommended dwell time of developers is 15 minutes for on-vehicle inspections.

2. Developer Sensitivities - Aqueous wet developers are the lowest in sensitivity and are not recommended for on-vehicle testing. Dry powder developers provide a higher sensitivity than aqueous wet developers but are also not recommended for on-vehicle testing. Nonaqueous wet developers consist of a powder suspended in a volatile liquid. They are the highest in sensitivity and can be used for all types of checks, but are used primarily for spot checks on the vehicle. Spray applications of the nonaqueous developer provide the highest sensitivity. The part should be at or near room temperature before applying the developer.

1.5.2.3 Ultraviolet Light Sources -

- A. The penetrants used in Type I processes fluoresce or glow brilliantly when exposed to ultraviolet light. A shield may be useful in preventing excess entry of white light from outside sources.
 1. One suitable light for fluorescent penetrant is known as the black light. Black light is a term applied to the visible radiant energy in that portion of the spectrum having a wave length of about 3200 to 3800 angstrom units. The black light utilizes a 100-watt mercury vapor bulb of the sealed reflector type which must be equipped with a suitable filter to eliminate undesirable light of longer wave lengths. This unit operates on 110-volt, 60-cycle alternating current, and requires a special transformer in the circuit. Sodium vapor lamps up to 400 watts are also available.
 2. When the black light is displayed on the part, intense fluorescence will mark crack-like discontinuities containing fluorescent penetrant. Regions containing no defects will be nonfluorescent or a dead purple under the black light. The developer subdues the background causing defects to stand out in sharp contrast.

3. The probable type and extent of defects is determined by noting the shape and area of indication. Cracks, seams, laps, lack of penetration, and cold shuts show up as fluorescent lines. Porosity or pitting corrosion is indicated by round fluorescent spots. Increasing spot size is indicative of a subsurface cavity. The larger the defect, the greater the volume of entrapped penetrant, which will increase the relative size of the developed indication.

1.5.3 Magnetic Particle Method

1.5.3.1 Description - Magnetic particle inspection is effective in the detection of surface and near surface defects in ferromagnetic parts. The reliability of the method is very high for cracks in the range of 0.050 to 0.150 inches (1.27mm. to 3.81 mm) in length. The method may be applied to installed or disassembled parts. The inspection is accomplished by inducing a magnetic field in the part, and applying a liquid suspension of iron particles or dry magnetic powder to the surface to be inspected. Defects in the part cause local bipolar perturbations in the magnetic field which attract the magnetic particles, producing visible indications by color contrast or by fluorescence under "black light." This method requires that the surface under inspection be thoroughly clean.

To locate a defect, the magnetic flux must pass at approximately right angles to the defect. Thus, it is helpful to know the preferential orientations that service-induced defects may take in the part. Discontinuities may be oriented in any direction, so that it is often necessary to magnetize the part in one direction, inspect, then magnetize in a direction 90 degrees to the first, inspect and demagnetize. This involves the use of both longitudinal and circular magnetization.

Types of defects which can be detected by this method include cracks, seams, laps, folds and nonferrous inclusions near the surface. Large surface defects can be detected by either ac or dc magnetization; small surface defects are best detected by ac magnetization; sub-surface defects are generally detected best by deep penetrating dc fields. DC equipment is used for stationary (bench) machine magnetic particle inspections, using both circular and longitudinal fields.

NOTE: When using high-amperage electrodes on parts to induce magnetism, care must be exercised to prevent arcing between electrode and part. Arcing or high temperatures may themselves produce defective conditions in the part.

1.5.3.2 Techniques

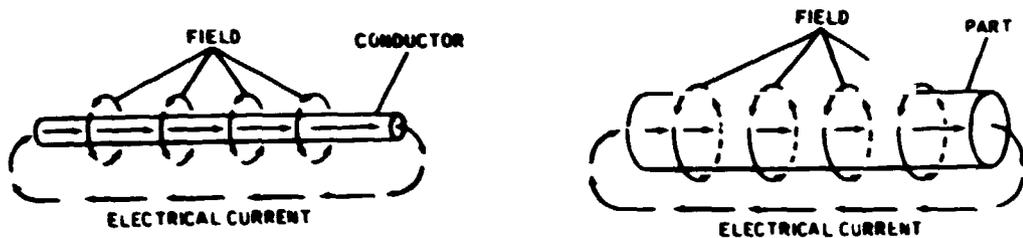
Circular Magnetization - Circular magnetization occurs when the current is passed directly through the part, thus creating concentric circles of magnetic lines about the axis of the part. This technique is depicted in the sketches of Figure 1-11. Circular fields about a central conductor electrode are used to inspect the inside of cylindrical holes or cavities, such as a large bolt hole in a lug. The electrode should have nearly the same diameter as the hole or cavity being inspected or, if it is considerably smaller, should be rotated about the inside surface for complete coverage. Cracks oriented parallel to the hole axis in the walls of the hole can be detected with circular fields.

Longitudinal Magnetization - Longitudinal lines of magnetic field are produced near the center of a coil through which a current is passing. A ferrous rod placed along the inside diameter of the coil will then have magnetic lines of force induced along paths generally parallel to its axis as shown in Figure 1-12. Cracks oriented along the circumference of the rod perpendicular to its axis can then be detected after applying the magnetic particle solution.

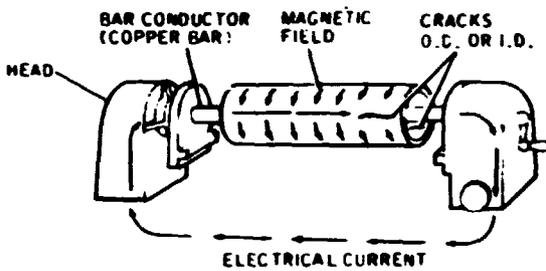
Permanent magnets having lifting forces greater than 30 pounds (133.4 newtons) can be used to induce fields into small, isolated areas where difficulty would greatly hinder the use of standard equipment. Orientation of the magnetic lines of force produced by the magnets, either bar or horseshoe, should be understood.

Portable Magnetic Particle Inspection System - Use the following procedures for the Parker Probe magnetic particle inspections.

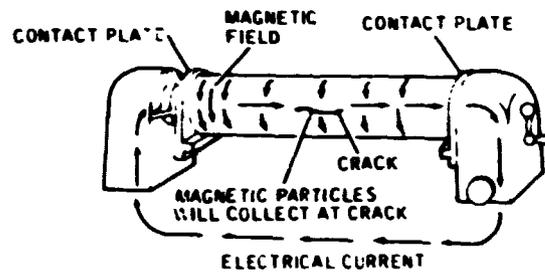
Parker Probe (Portable Hand Probe) Operating Instructions - The Parker Probe, illustrated by the yoke magnet shown in Figure 1-12, can only be operated on 105- to 125-volt alternating current, 60-cycle, single-phase, power supply. The maximum duty cycle ratio is two minutes "on",



EXAMPLES OF CIRCULAR MAGNETIC FIELD SURROUNDING A CONDUCTOR CARRYING AN ELECTRICAL CURRENT

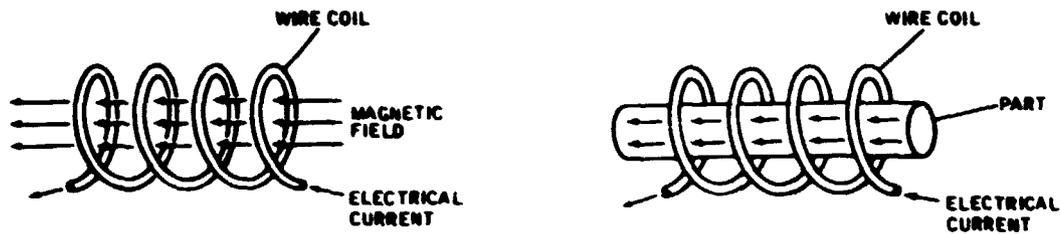


CIRCULAR MAGNETISM USED TO DETECT LONGITUDINAL CRACK IN HOLLOW TEST PART

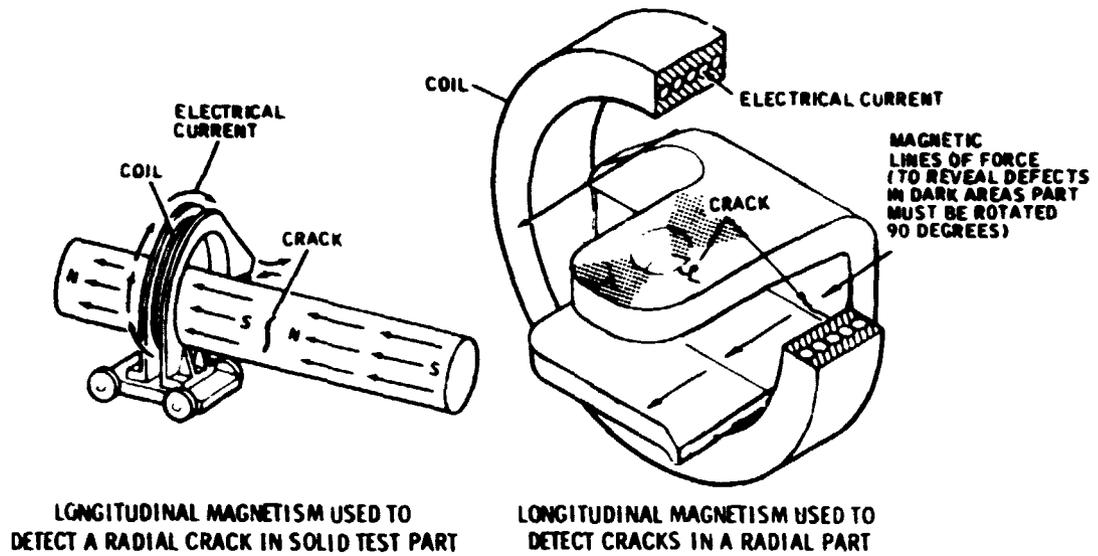


CIRCULAR MAGNETISM USED TO DETECT LONGITUDINAL CRACK IN SOLID TEST PART

Figure 1-11. Magnetic Particle NDE Circular Magnetization Technique

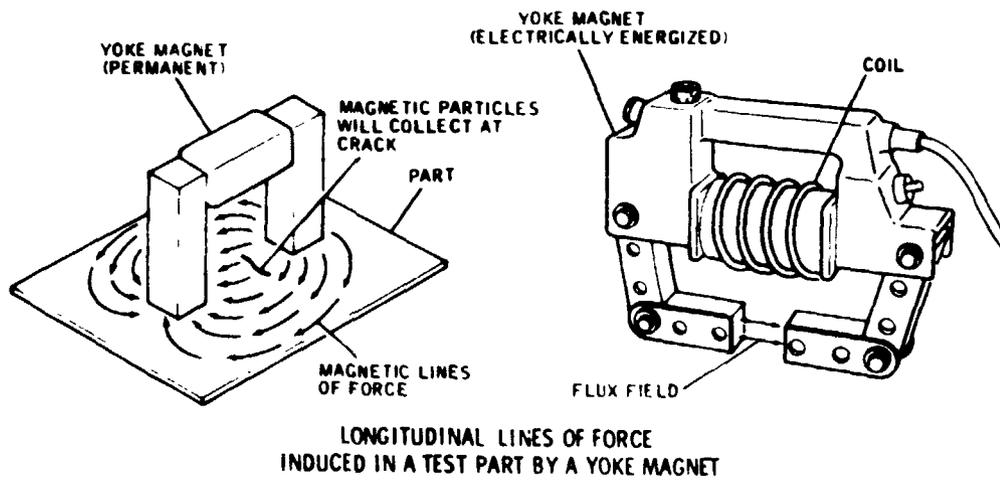


EXAMPLES OF LONGITUDINAL MAGNETIC FIELD AS PRODUCED BY A COIL



LONGITUDINAL MAGNETISM USED TO DETECT A RADIAL CRACK IN SOLID TEST PART

LONGITUDINAL MAGNETISM USED TO DETECT CRACKS IN A RADIAL PART



LONGITUDINAL LINES OF FORCE INDUCED IN A TEST PART BY A YOKE MAGNET

Figure 1-12. Magnetic Particle NDE Longitudinal Magnetization Technique

two minutes "off". This cycle applies to both the alternating current and direct current operations.

Operate the Parker Probe as follows:

- a. Place the selector switch in the AC or DC position in accordance with the detailed inspection procedure.
- b. Place the pole pieces on the part so that the suspected defect is at right angles to the poles.
- c. Press the "on" switch and magnetize the part.
- d. Use the wet continuous method to inspect for defects.
- e. Rotate the poles 90 degrees and repeat steps c and d to locate defects oriented 90 degrees from the first inspection.

NOTE: The pole pieces are adjustable. If a large area is being inspected, a pole spacing of 6 to 8 inches is recommended.

- f. Demagnetization:
 - 1) Place the selector switch in the AC position
 - 2) Place the poles in the inspection position.
 - 3) Press the "on" switch, and withdraw the Parker Probe from the part a distance of 2 feet (0.61m) before turning it off.

Demagnetizing High Strength Steel After the Performance of Magnetic Particle Inspection - All components or areas magnetized for magnetic particle inspection must be demagnetized after inspection to remove the residual fields. Failure to do

so may cause the residual magnetism to interfere with delicate avionics equipment, solenoids, or attract particles which may hinder operation of the part.

- a. Using portable hand probe: The local areas inspected on the airframe with the portable hand probe (Parker Probe) can be demagnetized to a serviceable condition by placing the selector switch to the AC position and withdrawing the probe from the part for a distance of approximately two feet (0.61m) before turning it off. This operation may have to be repeated several times to reduce the residual magnetic field in the part to the lowest possible level.
- b. Using stationary equipment: High strength steel parts that are inspected using DC amperage of 3,000 amps or over are found in some cases to be difficult to demagnetize. The stationary coil is considered to be the most effective method of demagnetizing the part. The demagnetizing operation may have to be repeated with the magnetic poles in the part reversed with each pass through the coil. See the operating instructions for proper demagnetization procedure.

1.5.3.3 Magnetic Rubber Inspection - A relatively new technique using a magnetic vulcanizing rubber compound can be used for surface and near-surface flaw detection on magnetic steel parts. The compound consists of a liquid rubber formulation containing black ferromagnetic particles. The liquid rubber is catalyzed and poured onto or into the part to be inspected. An external magnetic field is induced to cause the particles to migrate and concentrate at flaw sites in a manner somewhat analogous to conventional magnetic particle inspection methods. After allowing the rubber to cure for 30 minutes, a permanent cast impression of the part results, which can be removed and examined under ordinary light for flaw indications. A low-power microscope may be helpful in locating very small defects. Cracks or crack-like defects appear as black lines against a light gray background. The liquid rubber can be poured over the part surface, into bolt holes or recesses that may be difficult to inspect by other means.

The magnetic rubber inspection technique can be applied to steel parts that are not easily inspectable by the magnetic particle method or when ever a permanent record is desired. The method works on rough surfaces, through paint or plating, on any shape, and in very small or threaded holes. The magnetic rubber technique is relatively new and its reliability or applicability has not been fully assessed by industrial or military users, although it appears to have high sensitivity and resolution.

1.5.4 Eddy Current Method

1.5.4.1 Description - Eddy current inspection is effective for the detection of surface or near-surface cracks in most metals, cracks in fastener or bolt holes, and evaluation of fire damage or overaging of heat-treatable aluminum alloys. The method can be applied to airframe parts or assemblies where the inspection area is accessible for contact by the eddy current probe. An important use of eddy current inspection on the airframe is for the detection of cracking caused by corrosion or stress around fastener holes; however, cracks propagating from fastener holes can be detected by this method only after they extend beyond the fastener head. Special bolt hole probes are available and are useful, with the fastener removed, in locating cracks emanating from the wall of the fastener hole. Inspection is accomplished by inducing eddy currents into the part and observing electrical variations in the induced field. The degree of effect the material has upon the balance of the instrument varies directly with the material's conductivity or permeability.

The character of the observed field change is interpreted to determine the nature of the defect. A sharp meter deflection observed as the eddy current probe is moved over the inspection area will indicate a probable crack in the part (repeat inspection in opposite direction to verify) while a gradual deflection may be the result of a partial lift-off of the probe from the part. This lift-off may be caused by surface roughness/irregularities, or movement of the probe by the operator. When employing the Magnaflux ED-520 or the Nortec NDT-3 (using a single coil probe), the meter deflection for a crack indication will generally be upscale (to the right) for magnetic materials and downscale (to the left) for nonmagnetic materials. With certain instrument-probe-material combinations this rule does not apply. Therefore, a sharp meter needle deflection in either direction is an indication of a defect.

On a practical basis, cracks approximately 0.050 inches (1.27mm) long can be detected with high reliability. It is important to remember that crack depth affects the detection sensitivity providing the crack depth is less than the effective penetrating

depth of the eddy current field. A part-through surface crack of 0.030 inches (0.76mm) in length may have a depth of about 0.015 inches (0.38mm) which would not produce a large meter deflection.

1.5.4.2 Types of Equipment - Eddy current instruments are available in either the absolute or differential modes of operation. The absolute instrument contains a single coil probe which responds to all material variables that affect the material conductivity, surface lift-off or transfer impedance. The differential instrument uses a dual coil probe and circuits which cancels, in whole or in part, some variables that are seen by both coils, thus providing a more positive identification for cracks. The latter instrument is particularly suited for use on mildly magnetic steels.

Basically, eddy current instruments consist of a probe, electronic bridge and amplifier circuits, and an indicator. Controls on the instrument can be used to null the bridge circuits when "calibrating" the instrument. Discontinuities produce an imbalance or off-null condition in the bridge circuit and are thus indicated by the readout device.

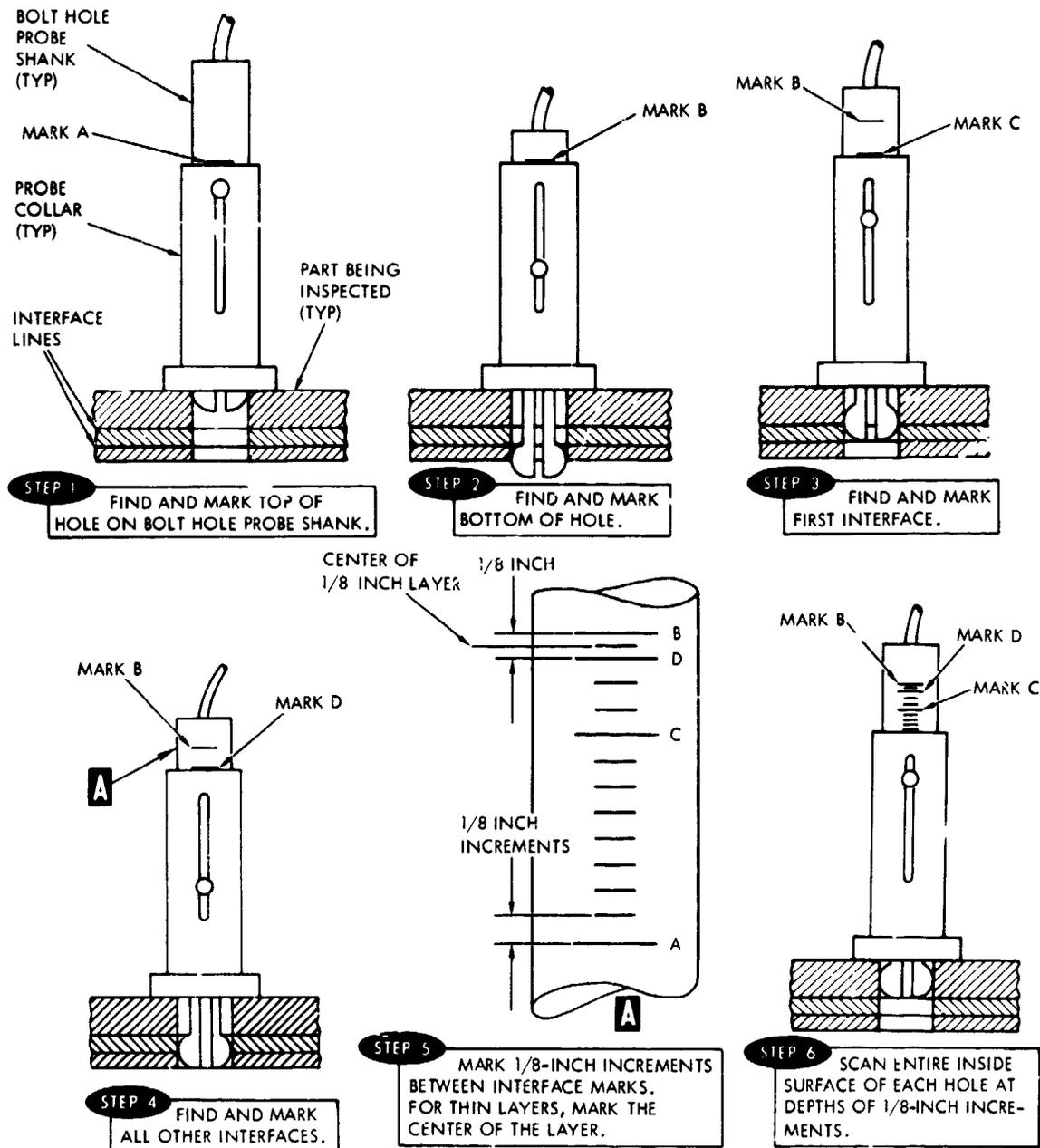
1.5.4.3 Techniques - Eddy Current Scanning Techniques - Eddy current inspection is essentially a scanning operation which generally involve flat panel areas, edges, fillets, fastener holes or areas around fasteners and between fasteners. These operations may be adversely affected by proximity to edges, holes or fasteners. A discussion of scanning around fasteners is given below.

Scanning Skin Panels Around Fasteners - It is mandatory to maintain a uniform probe-to-fastener spacing to obtain the best inspection when scanning around fasteners. It is recommended that a minimum of 1/8-inch (3.2mm) spacing be maintained when scanning around all fasteners (steel, monel, etc.) other than aluminum. No minimum spacing is required for aluminum fasteners, but whatever spacing is used should be maintained uniformly. To facilitate inspections of fastener patterns of the skin, a draftsman's circle template can be used as a probe guide.

Scanning Around Steel Fasteners - After determining that fasteners are steel on a non-ferrous part, an appropriate guide should be used to provide sufficient spacing between the fastener and eddy current probe to preclude erroneous crack indications. A constant spacing around the steel fastener must be maintained or the instrument circuits will be inbalanced by the varying magnetic effects due to the fasteners. A suitable spacing guide can be constructed of thin-walled lucite tubing of appropriate inside diameter so as to fit snugly over the steel fastener head or nut.

Bolt Hole Inspection - Where a bolt hole inspection does not designate each depth at which scans are to be made, a general method illustrated in Figure 1-13 is to be used as follows:

- a. Select and calibrate the appropriate bolt hole probe and instrument for the inspection.
- b. Determine the overall depth of the hole by inserting the probe into the hole to a depth where the meter indicator first comes to rest. Then place the probe holder on the part being inspected and mark where it stops on the shank of the bolt hole probe. Then move the probe through the bolt hole until the meter indicates that the probe coil has been moved completely out of the bolt hole. Again place the probe holder on the part and mark where it stops on the shank of the bolt hole probe.
- c. Move the probe back out of the bolt hole to the location where the meter indicator first came to rest and then advance the probe into the hole until the meter indicates that an interface between two of the mating parts has been reached. The meter indication will be the same for an interface and a crack. To be certain the meter deflection is not indicating a crack, move the probe to the center of the interface and adjust the meter needle to mid-scale. Then scan around the hole at that depth. A steady meter indicates an interface while deviation of the meter indicates a crack. The precise location of the interface can be found by moving the probe back and forth across the interface until the depth at which the meter



NOTE

1. THIS PROCEDURE IS TO BE USED ONLY FOR INSPECTING HOLES WHERE ALL LAYERS OF MATERIAL ARE THE SAME BASIC MATERIAL. WHERE DISSIMILAR METALS COMPRISE A SINGLE BOLT HOLE, THE SCAN DEPTHS WILL BE SHOWN ON THE SPECIFIC PROCEDURE.
2. INTERFACES CAN BE DETECTED BY MOVING THE PROBE THROUGH THE HOLE AND NOTING WHERE THE METER NEEDLE MOVES OFF-SCALE. THE POINT AT WHICH THE METER NEEDLE MOVEMENT CHANGES DIRECTION IS THE DEPTH INTO THE HOLE WHERE THE INTERFACE IS LOCATED.

Figure 1-13. Eddy Current Bolt Hole Inspection

deflection changes direction has been found. Then move the probe holder into place and mark the depth on the shank of the probe. Repeat this procedure as many times as required to find and mark all of the interfaces inside the bolt hole.

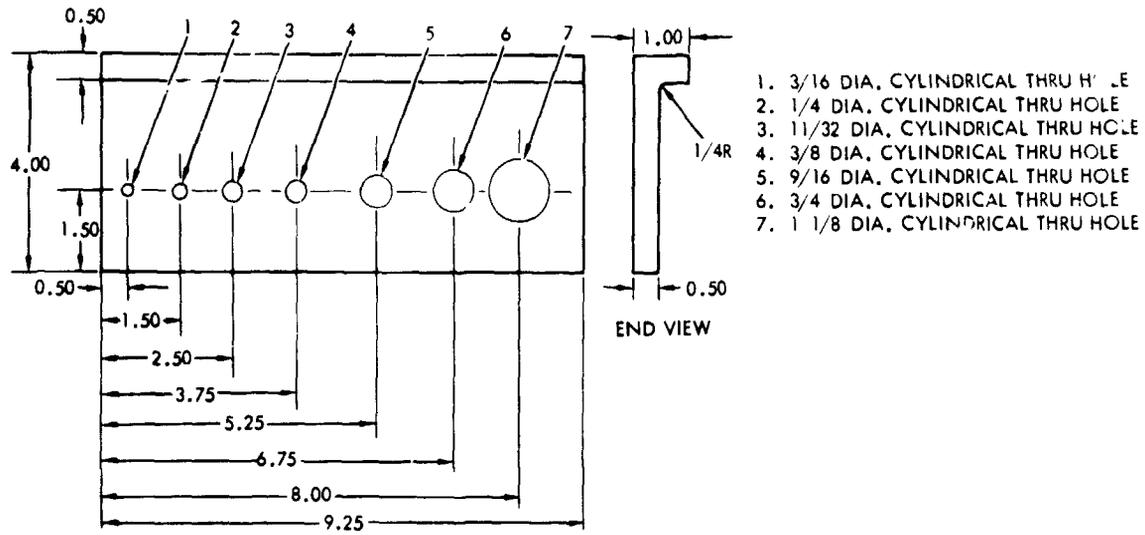
- d. The set of marks on the shank of the bolt hole probe represents the various thicknesses of the mating parts. Using these marks determine all the depths required to inspect all of the mating parts at depths of 1/8-inch (3.2mm) increments. Then set the probe to each of the depths and make multiple scans on the entire surface of the hole.
- e. A sharp meter deflection indicates a crack in the bolt hole.

Inspecting Areas of Limited Access - Many surfaces designated for eddy current inspection cannot be inspected using a regular general purpose probe. In such cases, right angle probes having various lengths of the tip can be purchased or made locally to provide the probe shaft clearance needed. The right angle tip containing the coil should be of sufficient length to provide clearance over fastener heads, nuts, angles and the like, when the tip is placed on the inspection surface.

1.5.4.4 Eddy Current Instrument Calibration - Two types of eddy current crack detection equipment are used in formulating the eddy current procedures in this manual: Magnaflux ED-520 and Nortec NDT-3. Figure 1-14 shows the design of a calibration standard - made of the pertinent material - which is appropriate for these calibrations.

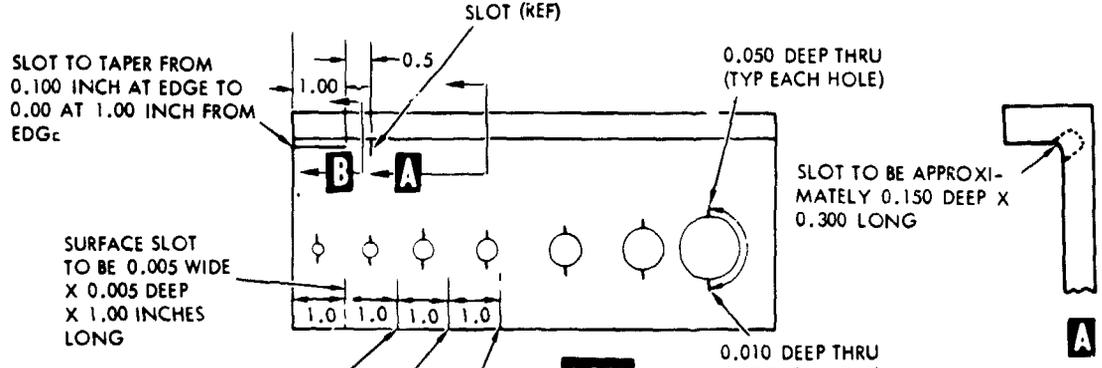
Magnaflux ED-520 - Calibration

- (1) Set the selector switch to the TEST position. Meter indication should be above the red line. A meter reading below the red line indicates that recharging of batteries is required, while fully charged batteries will give a reading substantially above the red mark, say 450 on the meter scale.



1. 3/16 DIA. CYLINDRICAL THRU HOLE
2. 1/4 DIA. CYLINDRICAL THRU HOLE
3. 11/32 DIA. CYLINDRICAL THRU HOLE
4. 3/8 DIA. CYLINDRICAL THRU HOLE
5. 9/16 DIA. CYLINDRICAL THRU HOLE
6. 3/4 DIA. CYLINDRICAL THRU HOLE
7. 1 1/8 DIA. CYLINDRICAL THRU HOLE

END VIEW



SLOT TO TAPER FROM 0.100 INCH AT EDGE TO 0.00 AT 1.00 INCH FROM EDGE

SURFACE SLOT TO BE 0.005 WIDE X 0.005 DEEP X 1.00 INCHES LONG

SURFACE SLOT TO BE 0.005 WIDE X 0.010 DEEP X 1.00 LONG

SURFACE SLOT TO BE 0.005 WIDE X 0.020 DEEP X 1.00 LONG

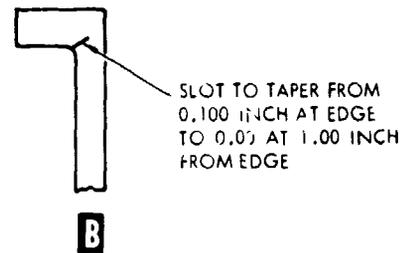
SURFACE SLOT TO BE 0.005 WIDE X 0.050 DEEP X 1.00 LONG

NOTE

1. MACHINE FINISH TO BE $\sqrt{63}$, MAXIMUM
2. ALL TOLERANCES TO BE ± 0.02 INCHES EXCEPT SLOT TOLERANCE TO BE ± 0.002 IN. ON WIDTHS AND $\pm 10\%$ OF DEPTH ON DEPTHS.
3. ALL HOLES TO BE SLOTTED TYPICALLY WITH TWO THRU-HOLE CUTS. ONE SLOT TO BE 0.010 IN. DEEP BY 0.005 WIDE AND THE OTHER SLOT TO BE 0.050 IN. DEEP BY 0.005 WIDE. EACH SLOT IS TO BE APPROX 180° FROM OTHER SLOT IN THE SAME HOLE (SEE ABOVE).
4. CALIBRATION STANDARD REQUIRED FOR FOLLOWING MATERIALS:

MATERIAL	STANDARD
ALL ALUMINUM ALLOYS	2024-T6
ALL TITANIUM ALLOYS	Ti-6Al-4V
ALL STEEL ALLOYS (MAGNETIC)	4340
(LOW MAGNETIC)	300M

5. ALL CALIBRATION STANDARDS TO BE PERMANENTLY LABELED SHOWING ALLOY AND METAL, AND SLOT DEPTHS.



SLOT TO TAPER FROM 0.100 INCH AT EDGE TO 0.00 AT 1.00 INCH FROM EDGE

B

Figure 1-14. Eddy Current Instrument Calibration Standard

- (2) Connect the probe or test coil to either front panel PROBE connector.
- (3) Turn the selector switch to the "LO" sensitivity position.
- (4) Set the Lift-Off/Freq. and Balance control dials to zero (full counterclockwise).
- (5) Place the probe on the surface of the calibration standard which is representative of the metal to be inspected, and bring the meter pointer on scale by turning the Balance control.
- (6) If Step (5) does not bring the meter on scale, leave the Balance control at full clockwise position and advance the Lift-Off/Freq. control until the meter needle comes on scale (approximately 250).
- (7) Place a piece of writing paper between the probe and calibration standard surface, and note meter reading. Remove the paper and note the difference in meter reading. Readjust the Lift-Off/Freq. control (and Balance control if necessary to keep the meter pointer on scale) until the same meter indication is obtained with and without the paper shim. This is most easily accomplished by noting the direction of meter deflection when the paper shim is pulled from beneath the probe and turning the Lift-Off/Freq. control to deflect the pointer in the same direction.
- (8) Advance incremental control to MEDIUM and repeat step (7). Then advance sensitivity control to HI and repeat step (7).
- (9) It will generally be found that lift-off compensation can be obtained at more than one setting of the Lift-Off/Freq.

control. For maximum sensitivity, the Lift/Off Freq. control should be set at the lowest dial setting for which lift-off compensation can be achieved by the above procedure.

- (10) With a properly operating instrument and probe adjusted to the correct Lift-Off/Freq, scan the area of the calibration standard which approximates the area to be inspected in the specific procedures. For example, if a fillet radius inspection is specified, scan along the fillet radius of the calibration standard noting the meter deflection caused when the simulated cracks (transverse and longitudinal to the fillet radius) are scanned.
- (11) When the instrument is properly calibrated on the standard, place the probe on the part being inspected. It may be necessary to bring the needle back on scale with the Balance control. Lock the lift-off frequency control in position and begin inspecting the part per the inspection procedure.

NOTE: When two or more probes are to be used in performing a specific inspection procedure, the crack detector must be recalibrated at the time of changing probes. It is also necessary to recalibrate the instrument when using a single probe to inspect different part configurations (i.e., when changing an inspection area from around fastener heads to a fillet radius).

Nortec NDT-3 - Calibration

- (1) Turn Power Switch to Position 1.
- (2) Test batteries by depressing buttons 1 and 2. Each battery should give a meter reading of approximately 64 (± 2) microamperes.

- (3) Connect probe specified in procedure to be performed.
- (4) Set the X and R controls to the OPERATING POINT of the material being inspected, using an X-R chart supplied by instrument manufacturer or developed locally. Such a chart is shown in Figure 1-15 as an example.
- (5) Turn the fine gain to zero, and hold the probe on the calibration standard which is representative of the metal to be inspected.
- (6) Bring the meter needle on scale with the Level control. The only function of the Level control is to position the meter needle, and whenever the meter is off scale it should be returned using this control.
- (7) Increase the coarse gain to positions, 2, 3, and 4 each time bringing the meter needle back on scale with the Level control. If the Level control reaches zero before returning the needle on scale, reduce the coarse gain one position (position No. 3 in most cases) and increase fine gain control until needle reaches center of scale.
- (8) Place a piece of writing paper of 0.003-inch (0.076mm) thickness between the probe and calibration standard surface and note the meter reading. Remove the paper and note the difference in the meter reading. Locking the R control, readjust the X (and level control if necessary to keep the meter pointer on scale) until the same meter indication (+ 2 small divisions) is obtained with and without the paper shim. This is most easily accomplished by noting the direction of meter deflection when the paper shim is pulled from beneath the probe, and turning the X control in the opposite direction of this deflection. If locking R and adjusting X does not produce the desired results,

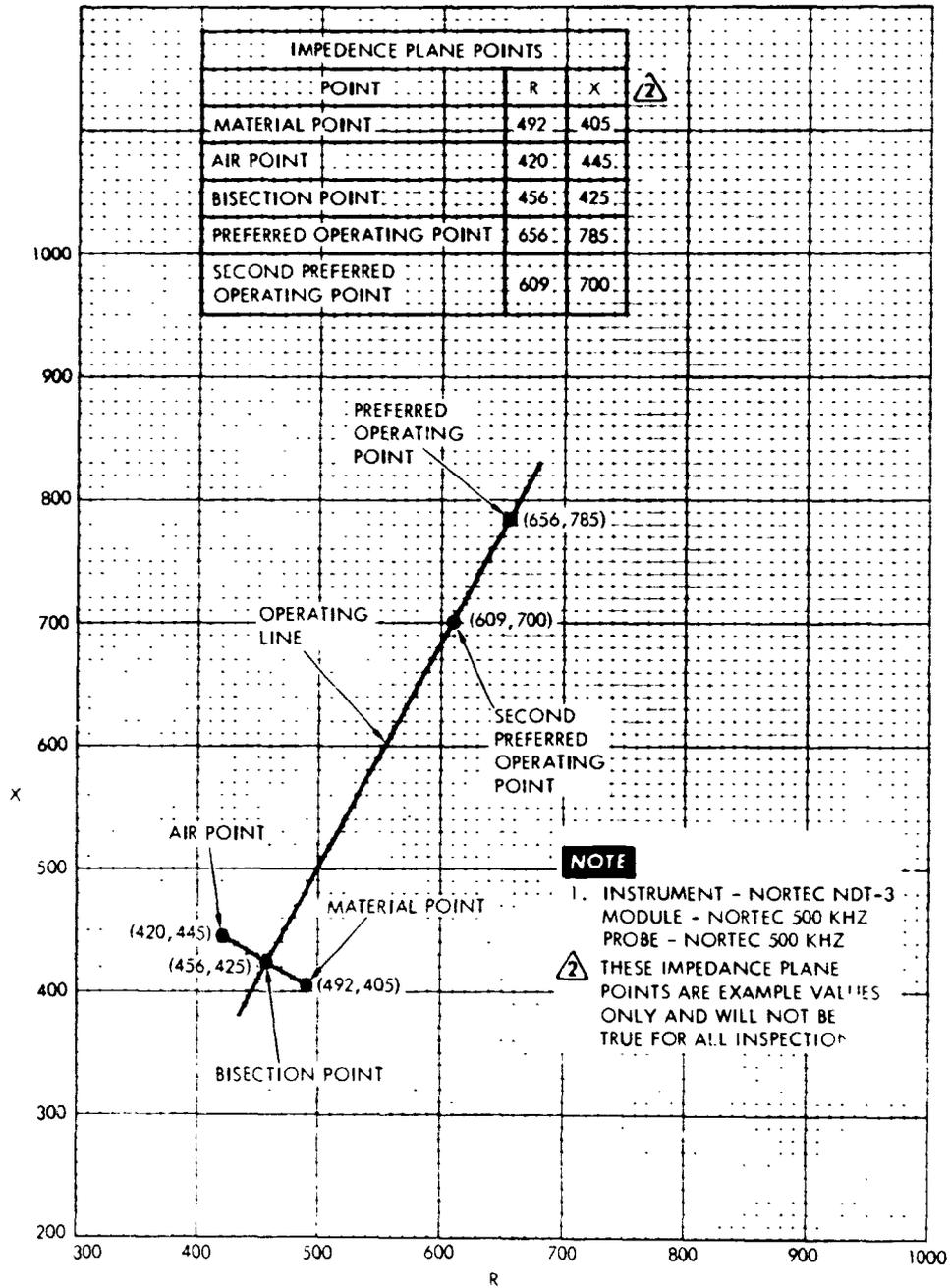


Figure 1-15. Example - X-R Diagram for a Nortec NDT - 3 Eddy Current Instrument

adjust both X and R controls one after the other until the same meter indication (± 2 divisions) is obtained with and without the paper shim.

- (9) With a properly operating instrument and probe which are lift-off compensated, scan the area of the calibration standard which approximates the area to be inspected in the specific procedure. For example, if a flat surface inspection is specified, scan along the flat surface of the calibration standard, noting the meter deflection when the simulated surface cracks are scanned.
- (10) When the instrument is properly calibrated on the standard, place the probe on the part being inspected. It may be necessary to bring the needle back on scale with the Level control. Lock X and R controls in position and begin inspecting the part per the inspection procedure.

1.5.4.5 Calibration of Electrical Conductivity Instrument

Description - Electrical (eddy current) conductivity measurements are often used to help determine the heat-treat or degree of fire/heat overaging of age-hardenable aluminum alloys. The conductivity is affected significantly by phase changes or granular size changes in the alloy and is correlatable to alloy hardness and strength. It is therefore usable as an indicator of the state of the material provided other material factors are correctly identified, e.g., alloy, cladding, heat treat history, and the like. Conductivity has a double-valued relationship to hardness - which is directly affected by heat treat status - thus requiring in many cases that hardness readings be made as well on the material at the same points as conductivity readings are made.

For aluminum alloys, the Nortec NDT-5 conductivity tester having a scale range of 26-60 IACS is recommended. The instrument gives readings in the International Annealed Copper Standard units. It is further recommended that the

instrument be calibrated by using conductivity standards traceable to the National Bureau of Standards, such as the Nortec Conductivity Standards 6843 and 6882, which have conductivities of 31.7% IACS and 42.7% IACS, respectively. If equivalent instrument and standards are used, the standard should have values in the aluminum conductivity range and be traceable to the NBS.

NOTE: It is important to consider the thickness, cladding, alloy/heat treat, time/temperature exposure data and the conductivity history for each specific part in order to reliably evaluate conductivity readings. A history of conductivity values for the part should be kept dating from assembly thru flight.

Procedure:

1. Connect probe to instrument.
2. Turn instrument on and allow a 5-minute warmup in the ambient test environment. Best results are obtained when instrument and test part are at or near normal room temperature. Instrument, standards and test parts should all be at or near the same temperature (within $\pm 10^{\circ}\text{F}$). When possible, measurements should be made in an ambient temperature range of 55°F to 85°F .
3. Depress battery test buttons to assure adequate instrument power.
4. Place clean probe flat on center of the low-value standard. Adjust the low-calibrate control until meter indicator is directly aligned with low-calibration mark on the scale.
5. Place the probe flat near the center of the high-value standard and adjust the high-calibrate control until meter indicator is directly aligned with the high-calibration mark on the scale.

6. Repeat Steps 4 and 5 until the instrument needle points directly to the scale calibration marks when alternately placed on the standards without the need for further adjustment of the calibration controls. If paint in excess of 0.008 inch (0.193mm) thickness exists on the surface which is to be evaluated, nonconductive shims of the same total thickness should be placed on the standards when performing Steps 4 through 6.
7. The instrument is now ready for use on the structure or component. Recheck battery and calibration at every 15 minute interval during constant use and at end of tests.
8. Apply the probe to a clean, smooth skin surface. Observe the precautions and limitations described in the instrument manufacturer's Operator's Manual.
9. Record and report the conductivity values at each measurement location.

NOTE: It is often necessary to use hardness data in combination with conductivity values to correctly identify an alloy or heat treat condition. In no case, however, should hardness indentations be made on aircraft structure without Engineering and Maintenance concurrence.

Assessing Airframe Skin Panels Heat Damage - Applicable specifications and/or other documents containing appropriate electrical conductivity and hardness/strength data are to be used in performance of this procedure. Refer to the conductivity instrument calibration procedure in this document. All procedures for TPS removal/replacement, metal cleaning, structure repair and standard operating procedures are to be used as required in performance of those functions.

This procedure, outlined in flow-diagram form in Figure 1-16, is to be used when a TPS tile (LI-900) is lost or damaged during the orbiter entry phase or deorbit or when the integrity of the TPS surface coating has been (destroyed) or

ORBITER HEAT DAMAGE ASSESSMENT PROCEDURE

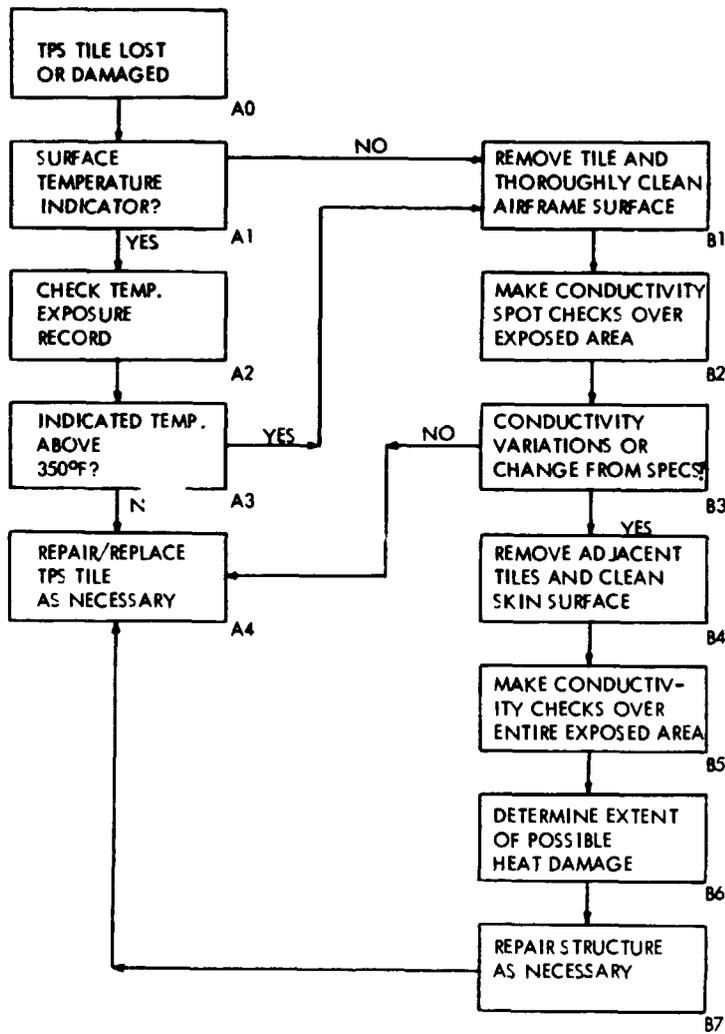


Figure 1-16. Procedure for Assessment of Heat Damage by Eddy Current Conductivity

suspected of being destroyed prior to or during entry. The conductivity history of the local airframe skin must be referred to for proper assessment.

When a tile has been thus identified, proceed as outlined below and illustrated in Figure 1-17

1. Check the structure and appropriate drawings for the presence of temperature indicators attached to the structure in the immediate vicinity of the damaged tile. When permanent color-change temperature indicators are present, determine if a color change has occurred to indicate the exceedance of specified temperatures (Baseline 350°F). When instrumented thermocouples or other remote indicating methods are employed, consult the recorded data to determine maximum temperature exposure.
2. If the indicated temperature has not exceeded 350°F (unless otherwise defined), repair or replace the damaged tile as necessary.
3. If the temperature has exceeded 350°F (unless defined otherwise) or if no temperature indicators present to indicate the temperature exposure of the immediate area of concern, remove the remaining tile debris and clean to provide a smooth bare airframe skin surface.
4. Using a properly calibrated electrical conductivity instrument, make measurements over the exposed area to fully represent the entire area. If the conductivity values vary more than 2% IACS or deviate appreciably from specification or baseline values, overheat damage is indicated and further evaluation is required (proceed to Step 6).
5. If conductivity values do not vary appreciably or deviate from acceptable values, no heat damage has occurred, and the TPS tile can be replaced for restoration to flight status.

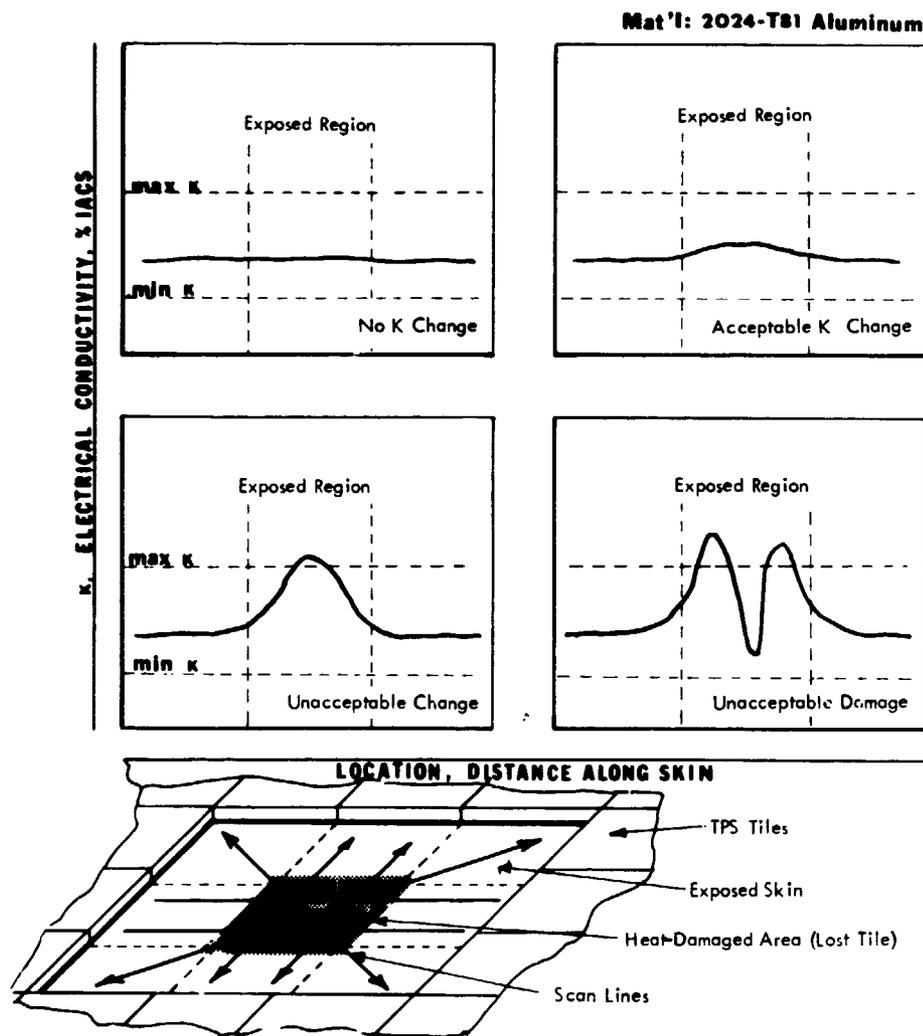


Figure 1-17. Example - Eddy Current Conductivity Assessment of Skin Panel After Loss or Heavy Damage of a TPS Tile

NOTE: Figure 18 lists typical conductivity and hardness values for bare aluminum alloys that may be affected on the Space Shuttle orbiter. These values are for reference only. Any conductivity results should be reported to the proper contacts so that an engineering interpretation can be made concerning the integrity of the suspect material.

6. When conductivity values indicate that heat damage has occurred, remove all adjacent tiles bordering on the affected area and clean the skin surface as in Step 3.
7. Make conductivity checks over the entire exposed area to define the extent and magnitude of heat damage. Record and map all conductivity values. If heat damage is significant, there will be three regions of interest: a direct heat-affected region, an unaffected region, and a transition region intermediate between them which is due to high heat transport away from the direct exposed region.

NOTE: It is possible that when the heat exposure is severe enough the aluminum skin can range from its design heat-treat status (unaffected region) to a completely annealed state (direct exposure region). Due to the double-valued nature of the conductivity versus hardness/strength relationship, conductivity measurements should be made along one or more paths leading from a point in the unaffected region continuously through the direct exposure area and to a point in the opposite unaffected region. See Figure 1-17 for a graphic sketch of the concept.

ALLOY/TEMPER	CONDUCTIVITY % IACS	HARDNESS, ROCKWELL
2024-F, 0	46 - 49.5	E55 Max, B10
2024-T3	28 - 32.5	E95 Min, B69 Min
-T4	28 - 34	E96 Min, B63 Min
-T6	36 - 42	B74 Min
-T81		
-T851	36 - 42.5	
-T86		
2124-F,0		
2124-T		
-T	Not Available	
-T851		
2219-F,0		E71 Max,
2219-T3		B77
-T6		E94 Min, B62
-T81	32	B77
-T87		
-T851		
7075-F,0	44 - 48	E67 Max, B22
7075-W	28 - 31	B30
7075-T6	31 - 35	E104 Min, B84 Min
-T73	38 - 43	B82 Min
7049-F,0		
7049-T	Not Available	
7049-T73		

FIGURE 1-18

REFERENCE CONDUCTIVITY (% IACS) AND ROCKWELL HARDNESS DATA
FOR BARE ALUMINUM ALLOYS

8. Report the results so that refurbishment decisions can be made.
9. After repair, replace the removed TPS tiles and restore the orbiter to flight status.

NOTE: Since this procedure uses a technique in which conductivity values on heat-affected areas are compared directly to values taken on unaffected areas on the same structure of known alloy and heat treat, it is not necessary to take hardness readings to assess temper, except for reference correlations.

1.5.5 Ultrasonic Method

1.5.5.1 Description - Ultrasonic NDE uses high-frequency sound waves as a probing medium to provide information as to the state of various materials. This method is effective for the inspection of most metals for surface and sub-surface defects. Fatigue and stress-corrosion cracks, interlaminar cracks and separations, porosity, weldment defects, sandwich debonds are among service-induced defects that are detectable by this method. Cracks as small as 0.050 inch (1.02mm) in length can often be detected with good reliability. The method requires that at least one surface of the part be accessible for probe (transducer) contact in the vicinity of the area to be examined. The inspection is accomplished by inducing the ultrasound into the part by a contacting probe using a piezoelectric element and picking up reflections of this sound from within the part. The detected ultrasonic reflections are electronically displayed on an oscilloscope and interpreted for indications of defects. Accessory devices (wedges) can be designed and fabricated to provide adequate probe coupling to curved surfaces or to change the angle of the sound beam. Wedges are usually made of lucite or some other non-abrasive, low attenuation, machinable material. A coupling fluid such as water or oil must be used to introduce the ultrasound into the part.

Ultrasonic indications can be observed through any of three common display modes. These are the A scan, B scan, and C scan modes, which are described in the references. The A scan mode is the one most often used in field or shop NDE, and commonly uses a cathode ray oscilloscope (CRO) for display.

Ultrasonic techniques can take the form of anyone of the following three basic techniques: 1) pulse-echo, 2) through-transmission, or 3) resonance, which are described in the references. The pulse-echo mode uses a single transducer which serves as both wave transmitter and echo receiver, except in the delta-scan arrangement in which one or more additional transducers are used to receive echoes, and/or re-radiated sound. The through-transmission technique uses two transducers -- a transmitter and a receiver -- usually placed directly opposite and facing each other with the suspect part placed between them. The resonance technique uses a single transducer to launch and receive multiple echoes which convey information

about thickness or nature of defect. The choice of basic technique depends on part geometry, defect location and orientation, type of defect, surface access, and other more or less influential factors. A defect is revealed because of reflections or scattering produced at the flaw's discontinuous interface, which provides an abrupt acoustical impedance change in the material. The detected "echoes" or "shadows" produce indications having characteristic amplitude and time relationships on the CRO.

Techniques - Ultrasonic techniques can be exploited in several wave modes: 1. longitudinal (straight) mode, 2. shear (angle) mode, or 3. surface mode. The type of wave and propagation velocity varies with these modes. The type of mode chosen depends on the location and orientation of the defect and its relationship to the accessible surfaces through which the ultrasonic beam must be directed. Figure 1-19 illustrates some of the applications of these techniques to airframe structure inspection. The references contain appropriate instructional material for use of these wave modes.

Any of these wave modes can be exploited in the pulse-echo or through-transmission techniques. The longitudinal wave is normally exploited in the resonance technique.

Reference Standards - To properly use the ultrasonic techniques, appropriate test blocks are required to establish reference specimens which simulate as near as possible the actual part in the suspect area and the defect characteristics that may be encountered. This reference specimen is often called a calibration standard. It is used to adjust the sweep (time) and amplitude controls of the ultrasonic instrument for proper interrogation of the suspect area, to establish inspection proficiency, and to verify inspection results. The standards are used not only in the initial instrument calibration (set-up) but to periodically check on the repeatability of the measurements.

Wave Mode Conversion - When a longitudinal wave traveling in a continuous medium impinges on a second continuous medium in which the wave velocity is

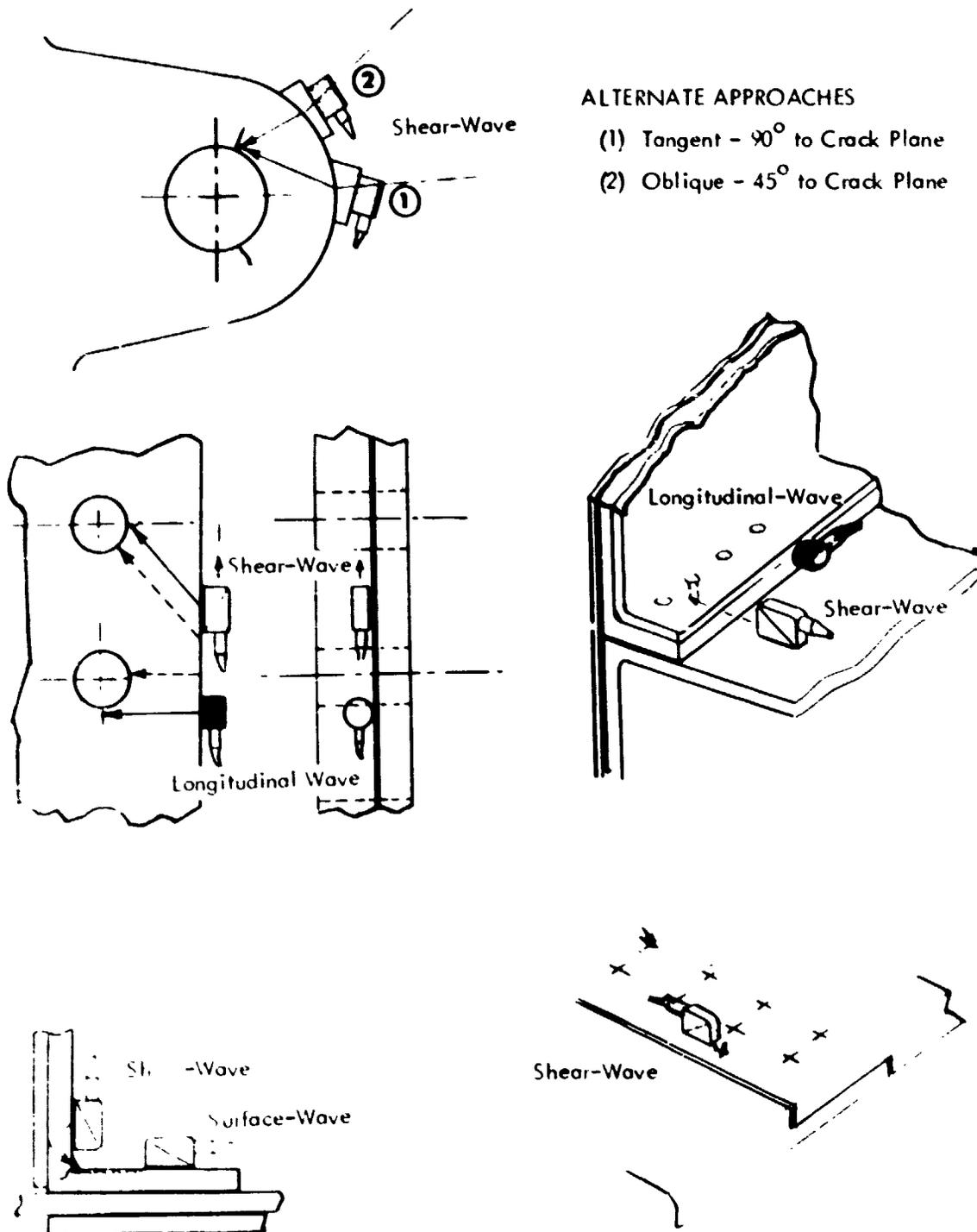


Figure 1-19. Typical Applications of Ultrasonic Longitudinal - and Shear-Wave techniques

different from the first medium and the angle of incidence is other than normal, two phenomena usually occur:

- (1) The beam is refracted according to Snell's Law, i.e., the beam direction will change abruptly at the interface by an amount proportional to the velocity differential, the angle of incidence, and either away from or toward the local surface normal depending on whether the wave velocity in the second medium is higher or lower, respectively, than in the first medium. In ultrasonic NDE on metals, the second medium is usually the one permitting the higher velocity.
- (2) Mode conversion will take place producing two or more distinct wave modes, one of which will be the original longitudinal wave and the other will be a transverse (shear) wave or, under some conditions, a surface (Rayleigh) wave. Since the shear wave travels slower than the longitudinal wave, the shear wave will normally be the component propagating closest to the local surface normal, i.e., it will have the smallest angle of refraction.

Critical Angles - Two critical angles of incidence are defined for the refracted longitudinal wave. The first of these is the incident angle at which the refracted longitudinal component travels along the surface (a planar surface is assumed). If the incident angle is increased further, the longitudinal component will be reflected entirely into the first medium and only the shear component will be propagated into the second medium. Increasing the incident angle further, an angle will eventually be reached such that the refracted shear component is directed along the interfacial surface. This is the second critical angle of incidence. If the incident angle is increased still further, the beam will be reflected entirely into the first medium and no wave energy will be imparted to the second medium. The second incident angle defines the conditions for total internal reflection and the creation of a surface or Rayleigh wave.

TABLE 4
FIRST AND SECOND CRITICAL INCIDENT ANGLES FOR ULTRASONIC WAVES
INCIDENT ON A METAL

MATERIALS	CRITICAL INCIDENT ANGLES	
	First Critical Angle (Longitudinal Wave)	Second Critical Angle (Shear Wave)
Lucite-Aluminum	25.7°	62.4°
Lucite-Titanium	26.6°	61.4°
Lucite-Steel	27.6°	57.3°

Mode versus Resolution - In mode conversion, the frequency of the wave is unchanged; only the velocity, therefore, the wave length is affected. Since the shear component travels slower than the longitudinal component, its wave length is shorter. Thus, the shear wave can often be exploited to provide increased resolution or sensitivity to small defects. In most metals, the shear component travels approximately half the velocity as the longitudinal component, thereby cutting the wavelength in half, or conversely, doubling the resolving power.

The mode-conversion phenomena of an angle-beam longitudinal wave can be exploited to provide optimum results for a specific NDE task. However, the unwanted wave component must not be allowed to reenter the receiving transducer to produce erroneous or confusing results. The unwanted component is controlled by proper design of transducers or angle wedges combined with a detailed knowledge of the geometry of the part being inspected. When it is desired to use the shear component, an incident angle having some intermediate value between the two critical angles is usually selected when possible. This choice results in the longitudinal component being excluded from entry into the test part. An alternative is to select an incident angle such that the unwanted component travels into and through the part without impinging on an interface so as to produce anomalous indications. If this condition cannot be met, then the unwanted component must be excluded from the part altogether. In ascertaining whether anomalous indications will result along the CRT baseline, the difference in velocity between the two wave components must be considered.

Transducers - Commercial transducers are available in a wide combination of frequency, size, mode, straight beam or focused, immersion or contact, and type of piezoelectric material. These combinations or variables are sufficiently described in the references. Most field ultrasonic NDE is performed with contact transducers using the basic pulse-echo technique.

Contact transducers are available in the longitudinal, shear, and surface-wave modes. The longitudinal mode transducer provides a 0-degree incidence and the shear-mode transducers usually provide 30-, 45-, 60-, 70-, 80-, or 90-degree refracted waves. Intermediate angles of incidence can be obtained, when required, by using a longitudinal-mode transducer attached to a properly designed angle wedge which provides the required angle of incidence/refraction. When the inspection surface is curved or contoured, such as on a lug, a longitudinal-mode transducer is used with a machined angle wedge which provides the proper angle and contains a curved surface which mates with the inspection surface on the part. The wedge may also contain other features such as an adjustable transducer clamp or a port for supplying the acoustic couplant.

1.5.5.2 Ultrasonic Inspection Procedures - A typical ultrasonic inspection may use the following steps:

- (1) Refer to the NDE procedure that relates to the part in question.
- (2) Select or prepare the appropriate calibration standards, wedges, and other fixtures required by the procedure.
- (3) Gain adequate access to the part; prepare the part for inspection by removing loose paint, dirt, scale, etc.
- (4) Set-up the instrumentation by using the reference standard (and other fixtures when appropriate) to obtain the prescribed defect pattern on the instrument CRT in accordance with the instructions provided in the procedure.

- (5) Apply couplant to the inspection areas on the part.
- (6) Scan the part according to the detailed instructions given in the procedure.
- (7) Locate and mark all indicated defects, report results.
- (8) After inspection, remove the test equipment, clean the part, and restore the craft to flight status.

1.5.5.3 Calibration Procedures -

- A. Longitudinal Pulse Echo Technique - A typical instrument calibration procedure relating to a pulse-echo longitudinal wave test mode such as would be performed in step 4 above is given below. The Sperry UM 715 Reflectoscope has been selected as the test instrument. Refer to Figure 1-20 for an illustration of the technique, calibration standard, and CRT presentation.

Initial Longitudinal Wave Calibration

NOTE:

For each specific inspection procedure use the following settings but substitute the calibration standard(s) and transducer(s) prescribed in the specific procedure.

a. Equipment:

- (1) UM 715 with 10N pulser-receiver
- (2) Transducer, SFZ, 57A2214, 5.0 MHz, with connecting cable, or as specified in procedure
- (3) Couplant, light oil
- (4) Calibration standard, Figure 1-20, as illustrated or as specified in procedure

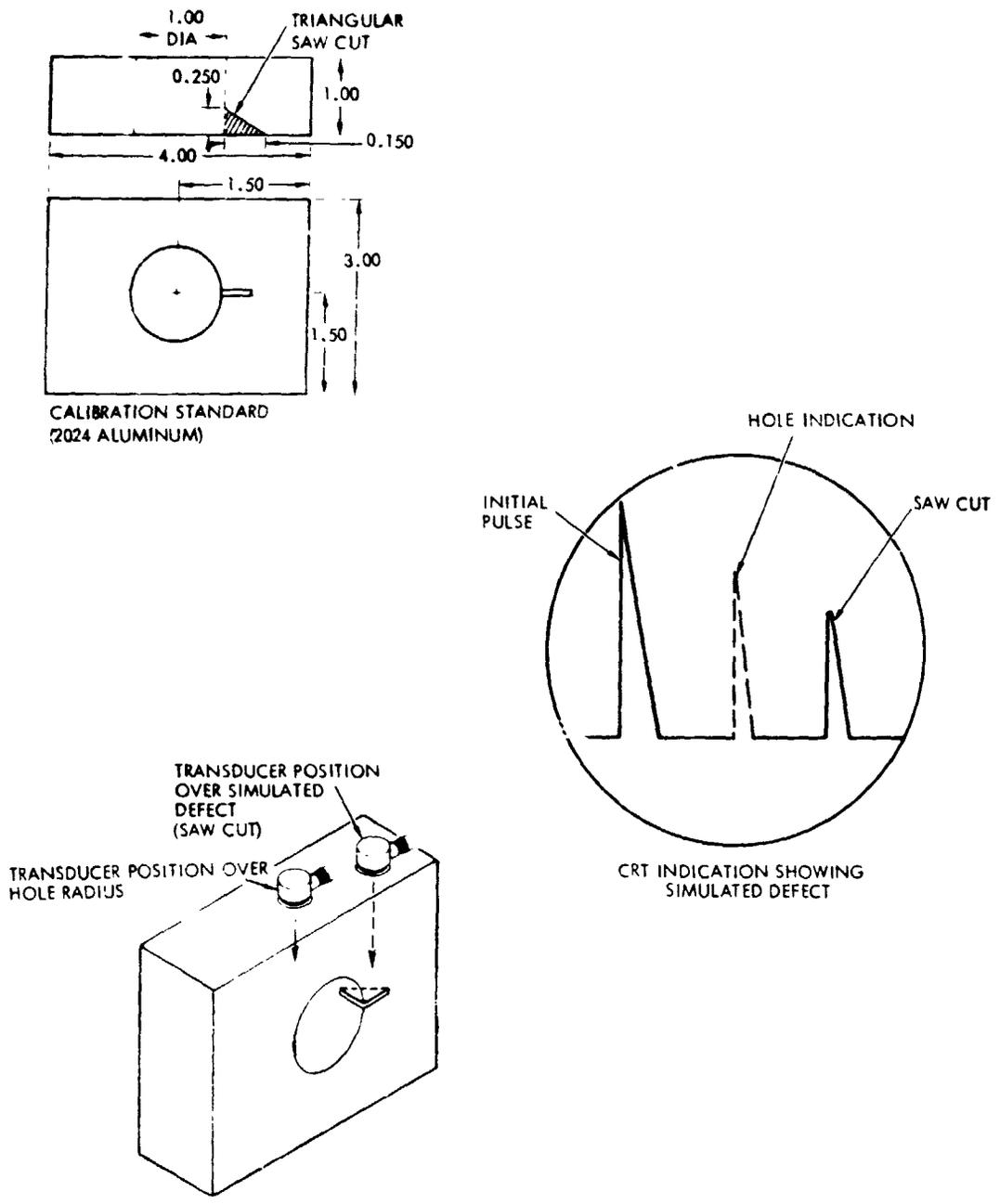


Figure 1-20. Initial Ultrasonic Longitudinal Wave Calibration

b. Procedure and preliminary settings

- (1) Plug UM 715 into power source, connect transducer and cable to "R" or "T" jack, whichever provides the best signal.
- (2) Turn unit on and allow 10 minute warmup time.
- (3) Set controls as follows (for aluminum standard):

SWEEP	
INCHES/DIV. DIAL/PRESET VELOCITY	1 x .1 DIAL 64
PULSE LENGTH	MIN.
REJECT	Minimum
SENSITIVITY	
Multiplier Switch Dial	X0.1 1
FREQUENCY	Match to transducer (2.25, 5.0, or 10.0)
TEST SWITCH	Normal
SWEEP DELAY	Position 1. Adjust coarse and VERNIER controls to position initial pulse on the left side of the CRT as illustrated.
SENSITIVITY	Readjust SENSITIVITY to show CRT display for an initial pulse as illustrated.
PULSE TUNING	Adjust for maximum response

c. Detailed settings:

- (1) Apply couplant and position transducer to obtain a signal from the simulated defect. Maximize signal response. If signal is not present, a slight adjustment of the following controls may be required to achieve the desired CRT indication as illustrated in appropriate procedure.

SWEEP VELOCITY	Adjust to position signal from simu- lated defect on right hand side of CRT
----------------	--

SENSITIVITY

Adjust until signal from simulated defect appears. Maximize the signal, then adjust signal to achieve 80 percent of saturated signal from the simulated defect as illustrated or in appropriate procedure

If the REJECT control is adjusted to reduce baseline noise, readjust SENSITIVITY control to obtain the 80% saturated signal indication.

- (2) Position transducer over the hole in the standard and observe CRT presentation as shown.
- (3) Slide the transducer from its position over the hole in a direction to put it over the saw cut and observe the CRT presentation.

NOTE

Response from saw-cut surfaces vary considerably, and the 80 percent amplitude should not be considered representative of the response from a crack of similar size.

- B. Initial Shear Wave Pulse Echo Technique - Lug Standard - A typical instrument calibration procedure relating to a pulse-echo shear wave test mode is given below as used on a clevis lug to inspect the bolt hole. The Sperry UM 715 Reflectoscope has been selected as the test instrument. Figure 1-21 illustrates the technique, calibration standard, and CRT presentation for this technique.

NOTE

INITIAL SHEAR WAVE CALIBRATION

For each specific inspection procedure use the following initial settings but substitute the calibration standard(s) and transducer(s) prescribed in the specific procedure.

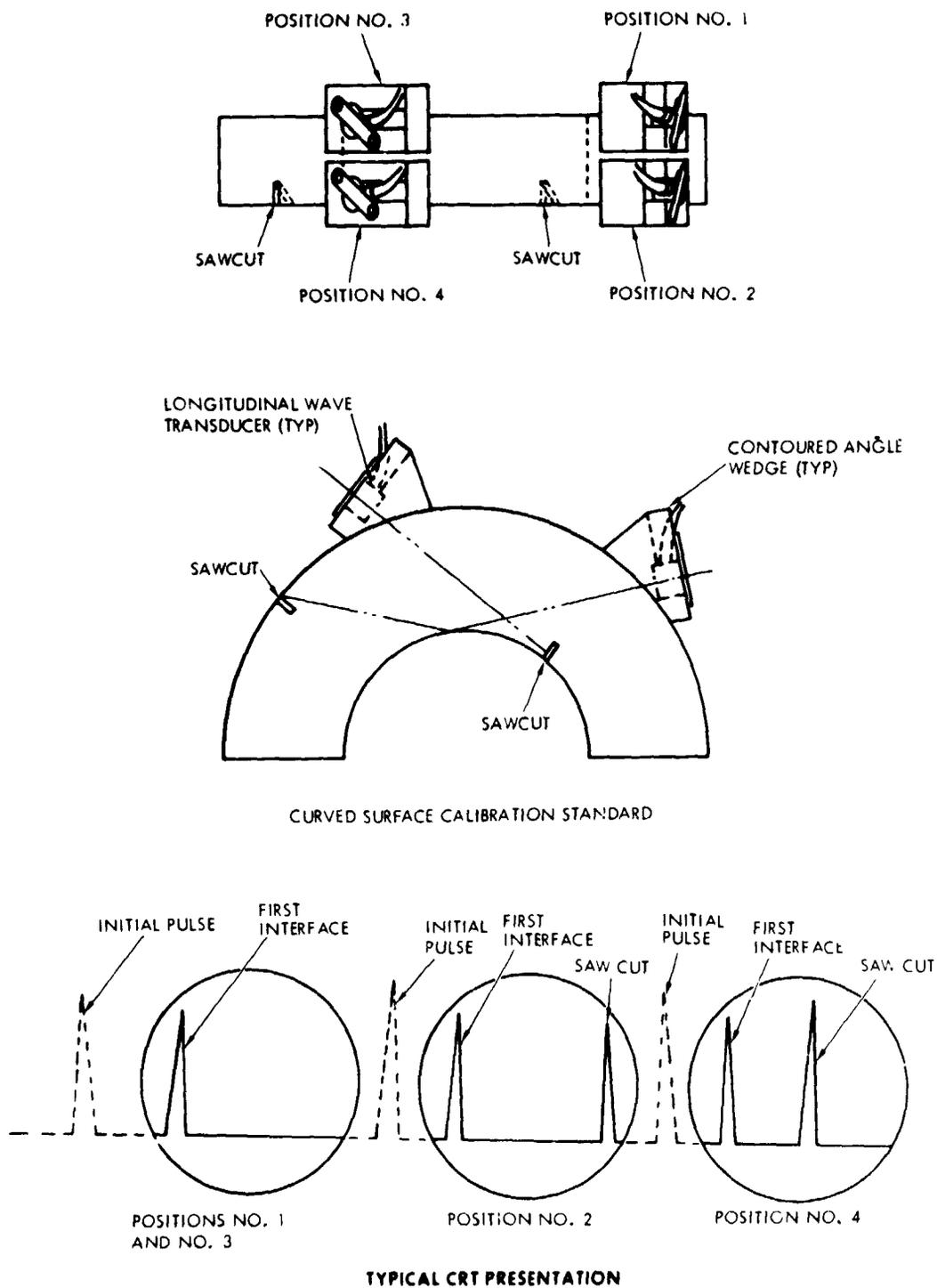


Figure 1-21. Initial Shear Wave Calibration - Lug Standard

a. Equipment

- (1) UM 715 with 10N pulser receiver
- (2) Transducer, SFZ, 57A2214, 5.0 MHz, with connecting cable or as specified in procedure
- (3) Couplant, light oil
- (4) Calibration standard, as illustrated or as specified in procedure
- (5) Contoured angle wedge, as illustrated

b. Procedure and preliminary settings:

- (1) Plug UM 715 into power source, connect transducer cable to "R" or "T" jack, whichever provides the better signal.
- (2) Turn unit on and allow 10 minute warmup time
- (3) Set controls as follows (for aluminum standard):

SWEEP

INCHES/DIV.	1 x .0
DIAL/PRESET	DIAL
VELOCITY	.48
PULSE LENGTH	MIN.
REJECT	Minimum

SENSITIVITY

Multiplier Switch	X0.1
Dial	?
FREQUENCY	Match to transducer (2.25, 5.0, or 10.0)
TEST Switch	Normal
SWEEP DELAY	Position 1. Adjust coarse and VERNIER controls to position initial pulse on the left side of the CRT as illustrated.
PULSE TUNING	Adjust for maximum response

c. Detailed settings:

- (1) Apply couplant and couple transducer and wedge in either position No. 1 or No. 3 (Figure 1-21). Adjust sweep delay to position the first interface near the left side of the scope.

- (2) Apply couplant and position transducer and angle wedge in position No. 2 (Figure 1-21) to obtain signal from simulated defect and maximize signal. If signal is not present a slight adjustment of the following controls may be required to achieve the desired CRT indication as illustrated or in appropriate procedure:

Sweep Velocity	Adjust to position signal from simulated defect on right hand side of CRT.
Sensitivity	Adjust until signal from simulated defect appears. Maximize the signal, then adjust signal to achieve 80 percent of saturated signal from the simulated defect as illustrated or in appropriate procedure.

If the REJECT control is adjusted to reduce baseline noise, readjust SENSITIVITY control to obtain the 80% saturated signal indication.

- (3) Move the transducer and wedge to other positions and observe the location and amplitude of the signal on the CRT from the saw cut as illustrated.

NOTE:

The response from saw cut surfaces varies considerably, and the 80 percent amplitude should not be considered representative of the response from a crack of similar size.

- C. Initial Shear Wave Calibration - Bolt Hole Standard - This procedure is illustrated by the calibration standard technique, and CRT presentation shown in Figure 1-22.

NOTE:

For each specific inspection procedure use the following initial settings but substitute the calibration standard(s) and transducer(s) reflected in the specific procedure.

a. Equipment:

- (1) UM 715 with 10N pulser with receiver
- (2) Transducer SMZ 57A3064, 45 degree, 5.0 MHz, with connecting cable or as specified in procedure.
- (3) Couplant, light oil.
- (4) Calibration standard, Figure 1-22, as illustrated or as specified in procedure.

b. Procedure and preliminary settings:

- (1) Plug UM 715 into power source, connect transducer and cable to "R" jack.
- (2) Turn unit on and allow 10 minute warmup time.
- (3) Set controls as follows:

SWEEP

INCHES/DIV.	1 x .1
DIAL/PRESET	DIAL
VELOCITY	.42

MARKERS	OFF
---------	-----

PULSE LENGTH	MIN.
--------------	------

REJECT	Minimum
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SENSITIVITY

Multiplier Switch	X0.1
Dial	1

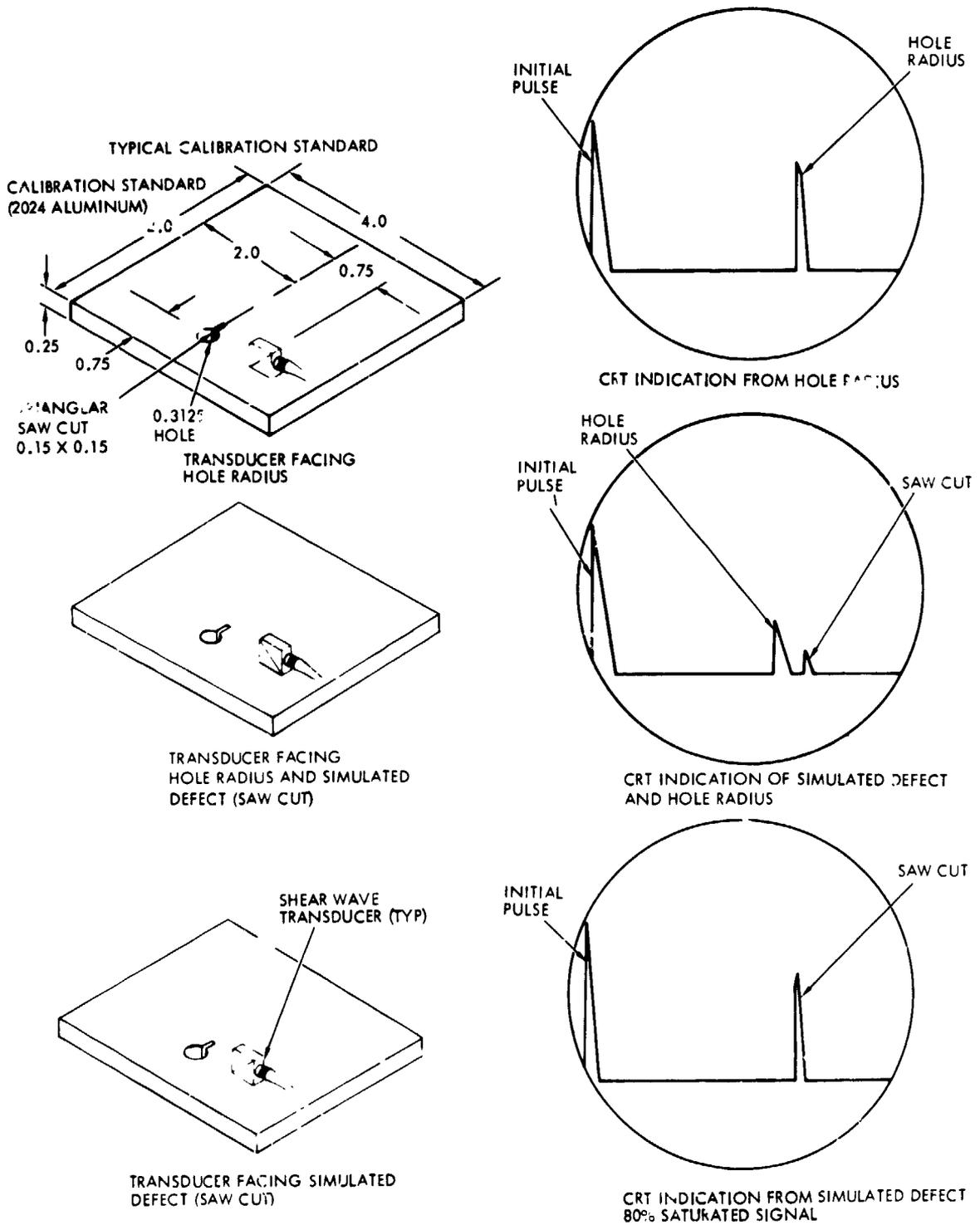


Figure 1-22. Initial Shear Wave Calibration - Folt Hole Standard

FREQUENCY	Match to transducer (2.25, 5.0 or 10.0)
TEST Switch	Normal
SWEEP DELAY	Position 1. Adjust coarse and VERNIER controls to position initial pulse on the left side of the CRT as illustrated.
PULSE TUNING	Adjust for maximum response.

NOTE

Sensitivity is normally affected by material differences, surface coatings on parts, and sealants within fastener holes and between adjacent parts.

c. Detailed Settings:

- (1) Apply couplant and position transducer to obtain a signal from the smallest simulated defect and maximize signal response. If signal is not present, a slight adjustment of the following controls may be required to achieve the desired CRT indication as illustrated or in appropriate procedure.

Sweep Velocity	Adjust to position signal from simulated defect on right hand side of CRT.
Sensitivity	Adjust until signal from simulated defect appears. Maximize the signal, then adjust signal to achieve 80 per- cent of saturated signal from the simu- lated defect as illustrated or in appropriate procedure.

NOTE

Noise or grass observed when the transducer is placed on test article may be decreased by altering the reject setting. Sensitivity must be readjusted to achieve the 80 percent saturated signal indication from the simulated defect.

- (2) Position transducer to indicate the hole in the standard and observe the CRT presentation as illustrated.
- (3) Carefully slide transducer in a lateral direction to indicate the simulated defect. By careful observation of the CRT, a very small defect can be resolved as illustrated, which shows a signal from the bolt hole and simulated defect simultaneously.
- (4) Now couple the transducer to the part to be inspected and obtain a signal from the fastener hole at the location marked on the CRT. Maximize this signal.
- (5) If the signal from the fastener hole is less than 100 percent, couple the transducer to the inspection part and obtain a signal from the fastener hole at the location marked on the CRT. Maximize this signal and adjust the sensitivity to achieve the same signal amplitude as that obtained from the hole in the standard, then perform the inspection in accordance with the applicable procedure.
- (6) Repeat the above steps for each hole.

1.5.5.4 Ultrasonic Thickness Testing - Various ultrasonic thickness

measuring instruments are available to measure the thickness of reworked (ground) areas accomplished to remove corrosion, scratches, etc. The instruments are applied to one side of the part and operate on the pulse echo principle. Modern ultrasonic thickness gages are portable, battery-powered, accurate, have high resolution, and may have a digital (numerical) readout. For ground areas having a smooth blend and wide contours, the Nortec Model NDT-120 and Branson Models 101 or 102 are suitable instruments. For narrow contours, a focused beam transducer such as that used in the Erdman Nanoscope is necessary to provide reasonable accuracy.

1.5.5.5 On-Board, Built-in Ultrasonic Sensors - The possibility exists that some ultrasonic transducers will be permanently installed at certain structural

critical areas to periodically monitor their integrity. The criteria for employing such devices may be that (a) the critical area is not accessible without unwarranted teardown, (b) the area has a safe-life design so that small cracks should be detected, and (c) the probable location of potential cracks can be accurately pinpointed through analysis or test. The transducers may be of standard or special configuration, bonded to the structure with a rugged long-life adhesive, and precisely positioned so as to interrogate the suspect area. Any of the three basic wave modes may be employed in the pulse-echo technique. The transducers can be either fixed or remote variable-azimuth units.

The input/output ports from all the transducers are wired into a central multiplexer from which the transducers are sequentially interrogated and the return signals recorded on tape or chart. Only a very short time is required to interrogate all transducers since a fully automatic programmed pulser/receiver is employed, thus almost completely eliminating the human element normally encountered in ultrasonic inspection.

The principles of operation are identical to the conventional ultrasonic systems, although calibration, checkout, and inspection procedures for each transducer are incorporated into the computer program that controls the entire testing process. Manual calibration, check-out, and interrogation can still be performed when desired. Since rapid interrogation is employed, the usual CRT display is not necessary in the system except for periodic manual operation. A conventional ultrasonic instrument can be used for manual operation, however.

On-Board System Calibration Procedure - To be determined by further development.

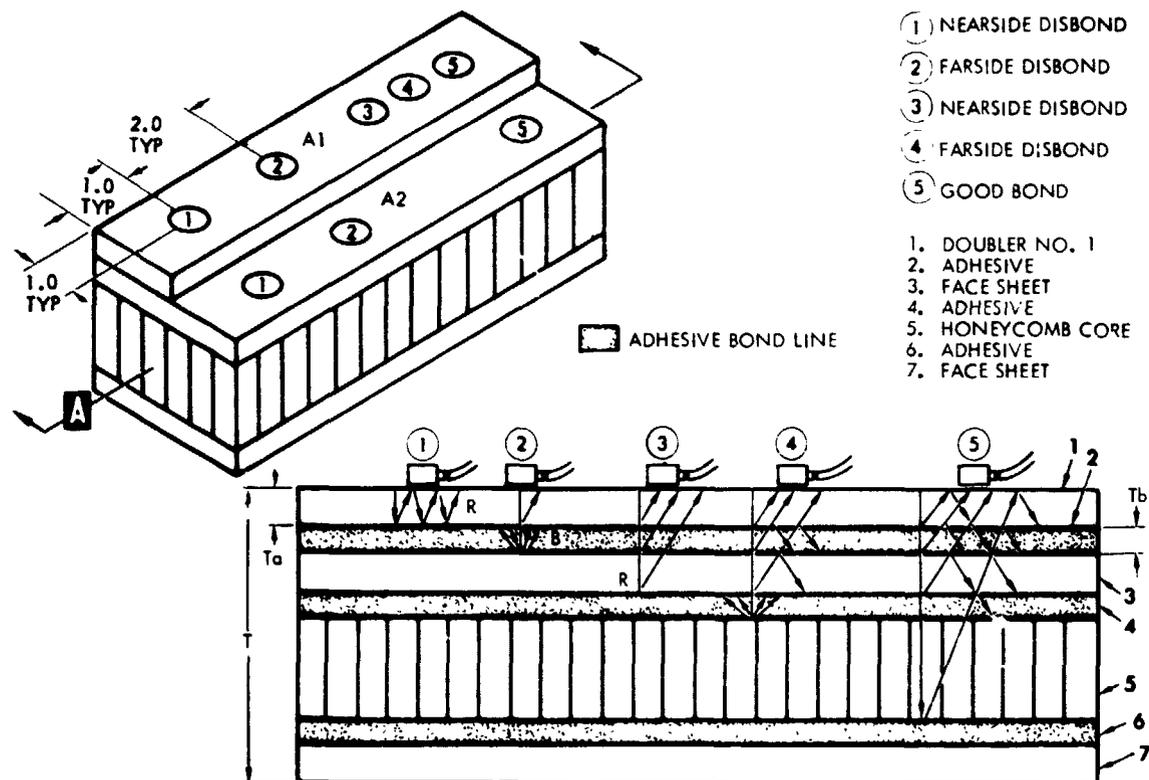
1.5.5.6 Sonic and Ultrasonic Resonance - Sonic and ultrasonic resonance methods using sound waves in the audible range of frequencies and beyond are useful for detection of debonds or core damage in adhesively bonded honeycomb panels or other composite structures such as bonded doublers. Structural areas on the Shuttle Orbiter where these methods may be applicable are the elevon and rudder/speed brake honeycomb skin panels, the aft body flap honeycomb skin panels, and the boron/epoxy bonded stiffeners on the thrust structure. Near-side and far-side debonds in honeycomb-facesheet and facesheet-doubler configurations are detectable.

Sonic Methods - Sonic testing instruments operate in or near the audio frequency range and operate basically by introducing a pressure wave into the specimen then detect the reflected, transmitted or resonant wave. The presence of a defect, such as a debond, in the path of the sonic energy changes the detected pattern relative to a pattern which denotes a defect-free area. The indication is usually displayed on a CRT within the instrument or on a metered scale.

Factors which generally affect sonic methods, particularly the resonant type, are part geometry and material, the number of bonded elements, size and thickness of honeycomb core, attachments to other structural elements such as ribs, brackets, bulkheads, etc. Reference standards are universally required.

The most common sonic test methods are briefly described below:

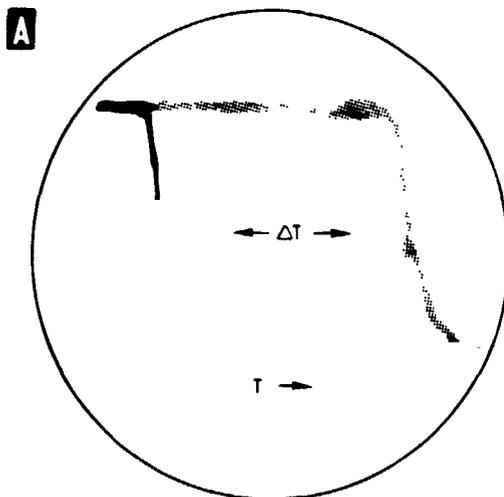
1. Fokker Bond Tester - This instrument uses an undamped piezoelectric natural-resonance probe to transmit low-frequency ultrasound into the material. The properties of the test piece are investigated by measuring the effects produced on the vibrational behavior of the crystal. The information is displayed on a CRO or microammeter showing frequency shifts or amplitude changes of the resonant peaks. Changes are produced by voids or debonds. The method has been useful on metal honeycomb, metal-metal laminates, and on resin matrix laminates.



COMPOSITE WITH INTERNAL DOUBLER AND THREE BOND LINES

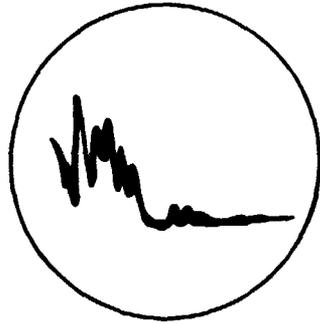
TYPICAL CALIBRATION STANDARD

1. THE ULTRASONIC ENERGY REACTS AT ALL INTER-FACES RANGING FROM THE UPPER FACE SHEET/ADHESIVE THROUGH THE COMPOSITE. THE FACTORS WHICH AFFECT THE ENERGY ARE ATTENUATION (A), THICKNESS (T), SCATTERING (B), REFLECTION (R) AND DENSITY OF CORE (D).
2. T_a - THICKNESS ALUMINUM FACE SHEET.
3. T_b - THICKNESS - BONDLINE.
4. NEARSIDE DISBOND - A DISBOND LOCATED ON THE TRANSDUCER SIDE OF THE ADHESIVE, IN THE ADHESIVE AND FAYING SURFACE INTER-FACE.
5. FARSIDE DISBOND - A DISBOND LOCATED ON THE OPPOSITE SIDE OF THE ADHESIVE FROM THE TRANSDUCER, IN THE ADHESIVE AND FAYING SURFACE INTERFACE.
6. ADHESIVE BOND LINE - A LAYER OF ADHESIVE BETWEEN TWO FAYING SURFACES.
7. THIS EXAMPLE IS INSPECTING ONE SIDE ONLY.

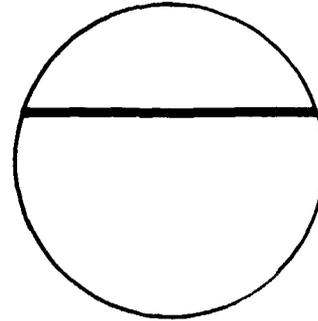


THE QUANTITY OF RETURNING ULTRASONIC ENERGY IS DISPLAYED ON AN OSCILLOSCOPE. THE BASE LENGTH OF THE SIGNAL ON THE OSCILLOSCOPE IS INDICATIVE OF THE ULTRASONIC PULSE TRANSIT TIME IN THE PART AND THE RETURNING ENERGY.

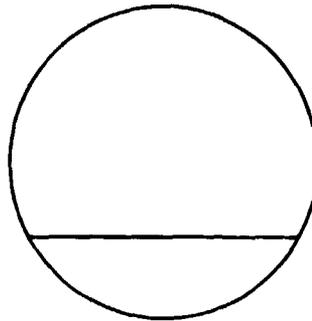
Figure 1-23. Principles of Ultrasonic Instrument Calibration - Honeycomb Bonded Structures



VIEW "A" GOOD BOND



VIEW "B" NEAR SIDE DISBOND (1) AND (3) FOR 5.0 MHz TRANSDUCERS AND ION² MODULE



VIEW "C" FAR SIDE DISBOND (2) AND (4) USING ION MODULE
ALL DISBONDS (1), (2), (3) AND (4) USING IN MODULE

TYPICAL CRT PRESENTATION

Figure 1-24. Principles of Ultrasonic Instrument Calibration -
Honeycomb Bonded Structures - Typical CRT Presentation

2. **Sonic Resonator** - Operates on acoustic interferometry principles by generating a sonic-frequency characteristic standing wave in a localized volume of the material. A resonant piezoelectric probe generates the wave which also senses the phase and amplitude of the standing wave and indicates the information as a discrete value on a meter. Structural defects or other features change the phase and amplitude of the standing wave. This technique can be used on metallic and nonmetallic composites, but is more suitable for nonmetallics. Face sheets greater than 0.060 inch (1.52mm) thickness or honeycomb greater than 2.5 inches (63.5mm) decreases the sensitivity. The instrument is useful on honeycomb (adhesive, diffusion, or brazed) and laminates.

3. **Eddy Sonic** - Uses an electromagnetic driver probe to produce eddy currents in a metal composite which excites acoustic waves. The material must be at least partially metal, but a couplant is not required. The acoustic energy is picked up by an acoustic sensor housed within the probe. The method has been used to test honeycomb and laminar composites for debonds, crushed or fractured core.

4. **Sondicator S-2** - This instrument is a very low frequency audio (25 Hz) device which requires no couplant. Amplitude and phase changes are sensed by a two-element probe and displayed on the instrument meter. One element of the probe transmits the sound into the test piece and the other element receives the reflected wave. Debonds in honeycomb and laminates can be detected by this instrument.

Principles of Ultrasonic Instrument Calibration - Honeycomb - Figure 1-23 illustrates the standards and technique to be used in this procedure. Figure 1-24 illustrates typical CRT presentations of signals for various bond-line conditions.

- a. The ultrasonic honeycomb inspection procedures utilize "ringing" pulse echo techniques to detect lack of bond or porosity in an adhesive bonded composite. This technique is not significantly sensitive to adjacent structural members such as ribs, stiffeners, etc., as are the low

frequency (sonic) resonance techniques. The instrument used is a Sperry UM-715 Reflectoscope and a 10N Pulser/Receiver plug-in unit. A single transducer transmits and receives the ultrasound. The quantity of returning sound, displayed on an oscilloscope in the form of closely spaced multiple echoes, is dependent upon interactions in the bonded composite. The base length of the pattern on the CRT is indicative of the ultrasonic pulse transit time in the part and the returning energy. Figure 1-24 in the CRT presentation illustrates the multiple signals returning from the various interfaces in a good bonded composite. Reference standards are necessary which represent the honeycomb structure in every factor, i.e., materials, face-sheet thickness,; honeycomb density, thickness and core size; far side face-sheet thickness; additional facesheets and doublers; and adhesive.

- b. In setting up the instrumentation, first select the appropriate honeycomb reference standard. The procedures should define approximate instrument settings; however, some settings may be altered to compensate for weak transducers. The sweep delay can move the trace to the left or right on the oscilloscope (CRT). Prior to starting the calibration, the Sweep Delay Coarse/Vernier knob is turned fully counterclockwise (CCW), which moves the trace fully to the left. If the defined good signal is not visible with the provided instrument settings, then the Sweep Delay Coarse/Vernier knob should be turned CW to shift the trace to the right. If too much of the trace is occupied with signal, then the sweep delay is turned CCW to shift the trace to the left.
- c. When the specified "good" signal is obtained with the transducer, then the transducer is placed over the nearside disbond, i.e., a disbond between the adhesive and facesheet. A loss of signal pattern should be observed on the CRT; however, in some procedures where a 5 MHz transducer of sufficient power is used, a ringing pattern will indicate a nearside disbond.

- (1) View B of Figure 1-24 in the typical CRT presentation illustrates the ringing signal received by the oscilloscope as a result of the sound being confined in the facesheet, when using a 10N module with a 5 MHz or higher frequency transducer.
 - (2) The transducer is then placed over the far side disbond area. A complete loss of signal should be noted on the oscilloscope for all far-side disbonds in all procedures, and all disbonds when using a 1N pulser module.
 - (3) View C of the figure in the typical CRT presentation illustrates a marked decrease in energy returning to the transducer over a farside disbond. This decrease is partially caused by the energy being scattered in the adhesive at a void between the adhesive and honeycomb core. A slight adjustment of the Reject control may be required to completely eliminate all signal noise on the base line. After this has been accomplished, recheck all above areas to verify the read-out.
- d. Procedures for parts with internal doublers and blade doublers are adjusted in a similar manner to the above.
 - e. The prime factors which affect void detection capability of the equipment are transducer frequency, operating frequency, connector receptacle, transducer type, pulser unit and couplant.

NOTE

This note applicable to 10N modules only. Due to thickness tolerances allowed during fabrication of tapered doublers or face sheets, it is necessary to provide a scan tolerance in the detail procedure, where applicable. Length of the scan areas are developed using a ten percent thickness change due to the taper.

- f. After all instrument adjustments have been made and rechecked on the standard, then the airframe part can be inspected. Changing any portion of the equipment will require a recalibration.

Typical Ultrasonic Honeycomb NDE Procedure

a. NDI equipment:

- (1) Reflectoscope, Sperry UM-715 or equivalent.
- (2) Transducer, 5.0 MHz, 1/4-inch (6.35mm) diameter, Longitudinal wave (shuntless), or equivalent.
- (3) Cable, 6 foot (1.83mm) Microdot/UHF Connector, Sperry, or equivalent.
- (4) Video Plug-in Module, 10N, Sperry, or equivalent.
- (5) Couplant, light oil.
- (6) Calibration Standard, as appropriate.

b. Instrument settings/calibration: Refer to Principles of Ultrasonic Instrument Calibration - Honeycomb

- (1) Determine instrument settings for the inspection area from the Initial Ultrasonic Calibration Data chart below and set instrument accordingly.

Sweep Delay	1
Sweep	
Vel Dial/Preset Inches/Div	Max. Dial 2 x 0.1
Coarse Vernier	1/2 CW
Pulse Length	Max
Sensitivity	Max
Pulse Tuning	Max
Reject	1/4 CW
Freq	5.0 MHz
Rec	T
Transducer	5.0 SFZ

- (2) Apply couplant and couple transducer to the appropriate area of the calibration standard, at a known good bond location.
- (3) Adjust sweep to cause the CRT signal to be similar to the good bond signal illustrated for this area.
- (4) Slide transducer over each disbond in the area of the standard, noting the characteristic CRT signal for each type of disbond. Slight adjustments of the sweep control may be required to obtain optimum CRT signals for the disbonds. After any sweep control adjustment, recheck calibration on the calibration standard.

NOTE

After achieving optimum disbond CRT presentation, recheck good bond signal. Amplitude of good bond signal may vary. Prior to inspection, make final check of disbond area CRT presentation.

c. Inspection:

- (1) Apply couplant and couple transducer to panel inspection area.
- (2) Scan inspection area on the honeycomb surfaces of each panel. Honeycomb boundaries are readily apparent. Scan 100% of the honeycomb panel surface unless otherwise instructed.
- (3) A signal on the CRT similar to one of the disbond signals observed during calibration will indicate a probable disbond of the same type as noted on the standard.
- (4) The area of the honeycomb perimeter which tapers, will give a CRT signal the same as a far side disbond; disregard this signal.

d. Mark and report all defect indications.

1.5.6 Radiographic Method

1.5.6.1 Description - Radiographic methods suitable for Space Shuttle NDE include a X-ray, b gamma-ray, and c neutron-ray radiography. The three methods use high-energy penetrating radiation to reveal internal conditions of materials by virtue of degrees of energy absorption in the material. These methods can complement each other in an inspection program to assess structure, materials or systems components that do not lend themselves to inspection by other NDE methods. For example, some materials that are opaque to X-rays are transparent to neutrons and conversely.

The three methods are used in the same way. That is, the part to be inspected is placed at an optimum distance from the radiation source in the path of the beam and a radiation-sensitive film is placed very close to and on the opposite side of the part. The exposed film is developed and "read" on a light table to interpret the indications. Sometimes it is desirable to replace the film with a fluorescent screen or an X-ray sensitive vidicon camera to evaluate the image in real-time on a television monitor -- techniques known as fluoroscopy and closed-circuit television radiography, respectively. The processes described for the purposes of this manual will use film only.

Penetrameters - Standard reference specimens are not required for radiographic techniques. However, a device called a penetrometer is required to indicate the contrast and definition which exists in a given radiograph. For X-ray and gamma ray radiography, the penetrometer is usually a piece of material of the same composition as that of the material being inspected. It represents a percentage of the test piece thickness and contains a combination of steps, holes or slots. The type generally used, for airframe inspection is a small rectangular metal plate, usually about 2% of the test object thickness, and containing drilled through-holes. Hole diameters of one, two and four times the penetrometer thickness are specified by ASTM. Penetrameters can also be prepared from wires or beads. For neutron radiography, the penetrometer usually contains small squares and rods of various thicknesses of the materials being tested attached to a neutron-transparent substrate to provide contrast and definition detail.

1.5.6.2 X-ray Radiography -

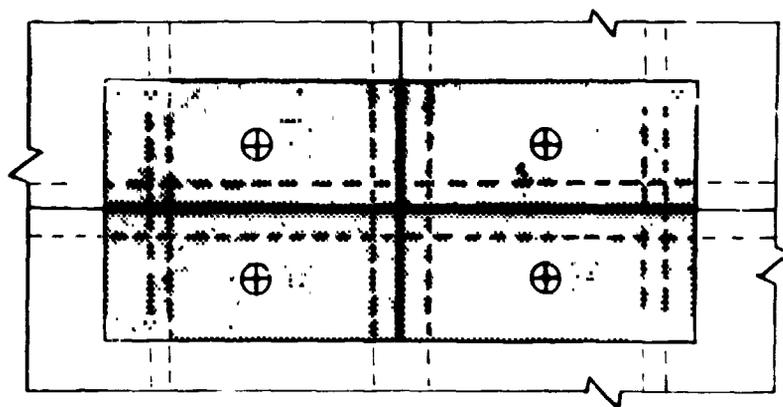
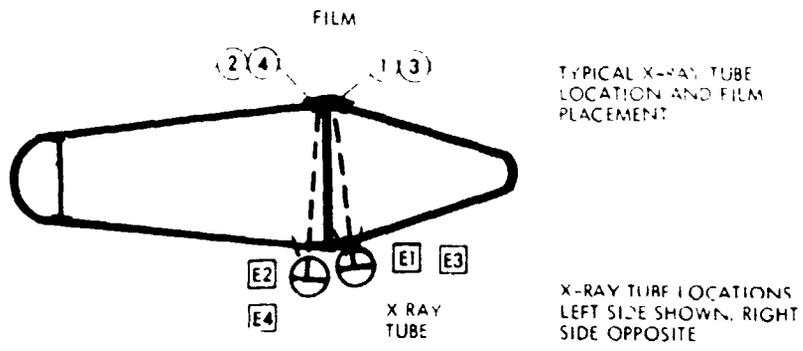
Description - X-ray inspection is used to show internal and external structural details of all types of parts and material. This method is used for the inspection of airframe structure for defects otherwise inaccessible for other methods of non-destructive inspection, or to verify conditions indicated by another method. A typical X-ray application of airframe structure is shown in Figure 1-25.

Indications are produced on the film by virtue of density and/or thickness variations in the material. The processed film exhibits structural details in the part by variations in film density, which is interpreted for indications of defects.

For detection of cracks or planar crack-like defects, the X-ray beam must be directed along (parallel to) the crack plane. Film exposure factors are established on the basis of material, part thickness (inspection area), film type, test beam geometry and like factors. The defect dimension and the beam path must be at least 2% of the total material thickness to achieve the theoretical sensitivity threshold. Practically, however, material and test variables will degrade this resolution somewhat.

Because of strict orientation requirements, practical sensitivity limits, part geometric features, and usual material mixes (e.g., steel or titanium fasteners in aluminum structure), the X-ray technique is rarely used for detection of small, tight fatigue cracks. Relatively large cracks in fail-safe structure, particularly when the crack can be opened by application of a transverse load, are detectable by X-ray means. Corrosion, missing or loose components, machining errors, internal mechanism arrangement, displacements, debris, and the like are capable of being displayed by the X-ray technique. Some types of internal core damage and water entrapment in honeycomb composite structures are detectable defects.

Film Density - Median film density is a density value or range of film density values which are considered essential for accurate film interpretation. The median film density values are required in individual X-ray inspection procedures for the



RADIOGRAPHIC INSPECTION DATA							
EXPOSURE NUMBER	KV	MA	FFD (INCHES)	TIME (SEC)	FILM		REMARKS
					TYPE	SIZE	
E1							EXPOSE 1
E2							EXPOSE 2
E3							EXPOSE 3
E4							EXPOSE 4

Figure 1-25. Example - X-Ray Radiography Application, Illustrating Symbols, Film Placement, and Data Table

specific structural problem area. The degree of film density is regulated by voltage (kilovolts), tube current (milliamperes), exposure time (seconds) and source-to-film distance (inches or meters). These exposure factors are interrelated, so that changing one of them may mean a compensating change in one or more of the others in order to achieve the same film density. It may be necessary to vary the MA, time, and KV settings due to differences in equipment, film and method of processing in order to achieve the specified density and quality. The references should be consulted for a discussion of the effects of these parameters on test results.

For radiographs of solid metal structures, the median is usually in the range of 1.5 to 3.0. The approach in using the film density range is illustrated in the radiography of a section of airframe having several thicknesses, in which case the kilovoltage and exposure time should be adjusted so that the image of the thickest portion has the minimum density (1.5) and the thinnest has the maximum acceptable density (3.0). In X-ray procedures for detection of water in bonded honeycomb structures, the median density should have the range of 1.0 to 1.5.

X-ray Procedure - The radiographic inspection procedure should specify the following test data:

1. X-ray equipment used, vendor's name and model, KV range
2. Type and size of film and film density required
3. Materials to be radiographed, min/max thicknesses.
4. Exposure factors; kilovoltage, milliamperage, time
5. Exposure geometry; source-to-film distance, source location and orientation, film placement
6. Number of exposures, number of films
7. Exposure sequence (if applicable)
8. Remarks

A Radiographic Data Chart giving this information, such as shown in Figure 1-26, should be developed for each critical area to be inspected and incorporated as part of the inspection procedure.

Any intervening material that can be removed for the exposure should be removed. For maximum resolution and sensitivity, the film should be placed as close to the suspected defect as possible, and the X-ray source should be aimed directly at the suspect area. If the beam is oriented at 6 degrees from the crack plane, the crack detectability percent will have decreased to 50% of the detectability at 0-degree orientation. Too great a source-to-film distance (greater than 120 inches or 3.05m) will result in low exposure contrast. The X-ray technique should favor the following:

RADIOGRAPHIC METHOD

1. Lowest KV for reasonable exposure time,
2. Greatest source-to-film distance for reasonable exposure time,
3. Minimum distance between film and part,
4. Proper source orientation for defect detection and minimum distortion,
5. Minimum thickness to be penetrated, and
6. Avoid overlapping or defect-concealing shadows in the radiograph.

Table 5 lists class and vendor for recommended equivalent film types. When films specified in individual procedures are not available, their equivalent film may be substituted as shown in this table. It may be necessary to make adjustments in exposure data when substituting film.

1.5.6.3 Gamma-Ray Radiography - This method of radiographic inspection is basically the same as the X-ray method except that the energy source used to expose the film is in the form of gamma rays which are produced by radioactive isotopes rather than a tube. Thus, exposure factors such as kilovoltage and milliamperage do not apply. Gamma rays are fixed emissions from disintegrating nuclei of radioactive materials and cannot be controlled by the user. The intensity level can be reduced, however, by masking the source with appropriate lead screens. This method is useful for inspecting dense materials for internal defects and other conditions.

The compact, power-independent nature of the radiation source facilitates the inspection of areas with restricted access such as small cylinders, pressure bottles, wing box interiors, engines, etc. The radiation quality of a gamma ray source is an intrinsic quantity which is not variable by external means.

TABLE 5. EQUIVALENT X-RAY FILM

ITEM		SOURCE OF IDENTIFICATION				
Class	Description	Eastman	DuPont	Ansco	Gavaert	Cenco
1	Very slow speed Ultra fine grain Highest contrast	R	NDT45	HD	D2	--
2	Slow speed Very fine grain High contrast	M T	NDT55 NDT65	B	D4	1M
3	Moderate speed Fine grain Medium contrast	AA	NDT75	A	D5	1R

For the purpose of this manual, the films listed for each class are equivalent. Results to be expected when using film from the various sources may vary slightly.

Radioactive materials decay with time so that the radiation intensity constantly decreases. The duration of such a source is given in half-life, which is the amount of time required for the radiation level to decrease to 50% of its initial value.

Some commonly used gamma ray sources are radium 226, cobalt 60, iridium 192, and thulium 170. The radium and cobalt isotopes produce gamma rays of great penetrating power capable of radiographing up to 8-inch (203mm) thickness steel. Hence, these isotopes may not be advisable for general airframe inspection. The iridium isotope has a useful penetration range up to 3 inches (76.2mm) of steel

and may be useful for inspection of main engines or landing gear components. The thulium isotope has a very low energy and may be useful for inspecting inaccessible structural components such as wing truss fittings and vertical stabilizer structure. Since the radiation level is low, long exposure times may be required. Some comparative characteristics of various radioactive gamma ray sources are given in Table 6.

The strength of a gamma ray source is given in curie units, which are indicative of the number of nuclear disintegrations per second. One curie is defined as 3.7×10^{10} disintegrations per second. The gamma ray output is directly proportional to both source strength and time of exposure, usually expressed as the product of strength (curies) and time (seconds). A physically small source will give less geometric unsharpness in the exposed radiograph and allow shorter exposures and shorter source-to-film distances.

Procedures for using gamma ray sources are essentially the same as for X-ray procedures. Gamma rays have biological effects similar to that of X-rays, so that safety precautions must be strictly adhered to. Radioactive sources cannot be turned on or off, requiring that they be normally housed in a thick lead box until ready for use. The sources should never be handled directly, but with tongs, strings or magnetic rods by thoroughly trained personnel.

1.5.6.4 Neutron Radiography - Neutron beams suitable for radiography are obtained from nuclear reactors and various man-made isotopes such as Californium 252 ($Cf-252$). This section is intended to describe the neutron radiographic method as based on portable systems using the $Cf-252$ source. $Cf-252$ is a miniature but intense nuclide that fissions spontaneously, emitting over 2×10^{12} neutrons per second per gram of material (55 curies).

Neutrons differ from X-rays and Gamma rays in a number of ways. Neutrons are electrically neutral particles that constitute all atomic nuclei except hydrogen,

TABLE 6. CHARACTERISTICS AND MERITS OF
RADIOISOTOPE SOURCES FOR
GAMMA-RAY NDE

	COBALT Co-60	IRIDIUM Ir-192	THULIUM Tm-170
Radiation Level RHF/Curie	14.5	5.9	0.03
Energy (MEV)	1.25	0.355	0.072
X-Ray Equivalent (KV)	2000 to 3000	300 to 800	100 to 300
Half-Life	5.3 Years	75 Days	130 Days
Moderator Half-Value Layer (Lead)	0.5 Inches	0.2 Inches	0.05 Inches
Penetration (Steel)	1 to 7 Inches	1/4 to 3 Inches	Very thin to 1/2 In.
Source Size	Small	Very Small	Small
Specific Activity	Medium	Very High	Highest
Cost	Low	Relatively Low	High
Other	Readily Available	Readily Available	Not Readily Available

which are liberated from the atomic nucleus through the fission reaction. A neutron interacts directly with the nuclei of bombarded atoms, either by elastic collision or absorption, subsequently inducing a nuclear decay process. The linear attenuation coefficient of neutrons varies greatly with the particular isotopes constituting the absorber and the speed of the incident neutrons. The neutron attenuation coefficients for various materials contrast strikingly with the X-ray or Gamma ray coefficients which depend upon atomic number and increases smoothly with atomic number. Figure 1-27 illustrates these differences between X-rays and neutrons as a function of atomic number.

Figure 1-27 shows the differences between the high neutron attenuation of hydrogen (H), boron (B), lithium (Li) and carbon (C), and the relatively low neutron attenuation of aluminum (Al), titanium (Ti), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn) and lead (Pb). Neutrons tend to be highly attenuated by the light elements, whereas X-rays are attenuated more by the heavy elements, characteristics that essentially reverse the roles of the two radiographic methods and render them complementary to each other for inspection of many airframe materials and components. Thus, with neutron radiography, NDE can be made of:

1. light materials encased in or behind heavy materials,
2. homogeneous materials, such as rubber, sealants and rocket propellant,
3. contaminants whose neutron absorption and scattering properties differ significantly from the base material,
4. composite or compound materials, and
5. thick samples impenetrable by X-rays.

Neutron radiography is thus applicable to inspection of boron/aluminum or boron/epoxy composites, nonmetallic honeycomb, adhesive layers in aluminum honeycomb or laminates, water entrapment in metallic honeycomb, corrosion, seals, and lubricants in pumps or other systems components, charges and fuses in

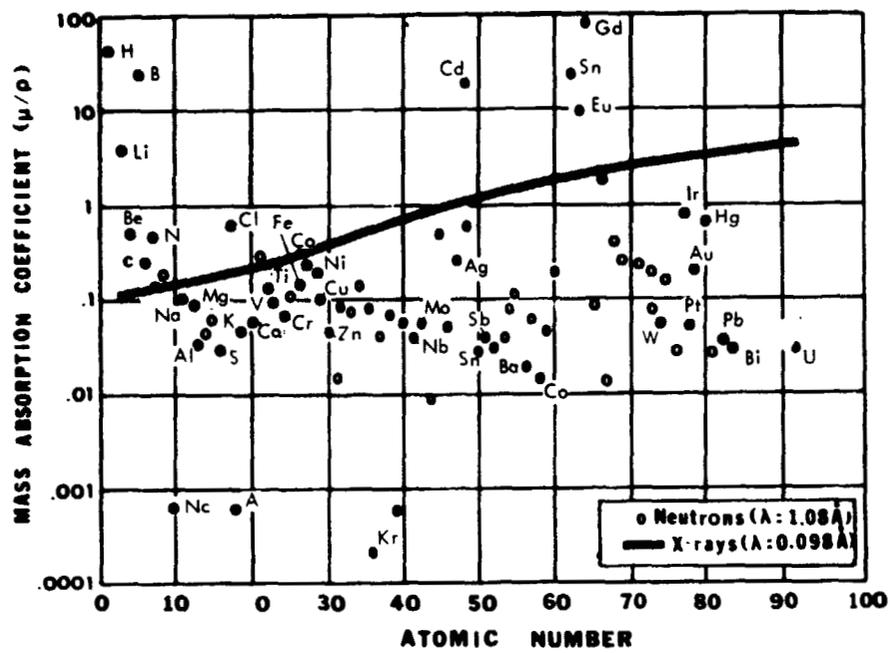


Figure 1-27. X-Ray and Neutron Mass Absorption Coefficients for Various Elements

explosive devices such as frangible bolts, and many similar uses for which X-rays and Gamma rays have poor applicability. The complementarity of the three radiographic methods, however, is apparent.

Neutron Radiographic Equipment - The basic neutron radiographic camera consists of the $Cf-252$ neutron source, a beam moderator system, beam collimator, biological radiation shields, and the imaging system. See Figure 1-28 for a diagram of a practical system. The collimator may be composed of a borated water-extended polyester lined with cadmium. The shield consists of lead boron- and lithium carbonate-loaded water-extended polyester and an outer shell. The $Cf-252$ source is located at the center of the moderator assembly, and the emitted thermal neutron beam is defined by a set of limiting apertures and the collimator system.

Neutrons do not interact with photographic film so that conversion from the neutron beam to an energy form reproducible by film is required. This is accomplished by a system consisting of a combination of thin gadolinium foil and one of several photographic films. When a thermal neutron is absorbed in the gadolinium foil, an electron or gamma ray is emitted which interacts with the photographic film to create an image. X-ray type films are applicable to this system. The films can be processed and interpreted by any qualified X-ray technician. From an operational point of view, the neutron radiographic method provides an extension of the X-ray and Gamma ray radiographic capabilities and should not be employed in lieu of them.

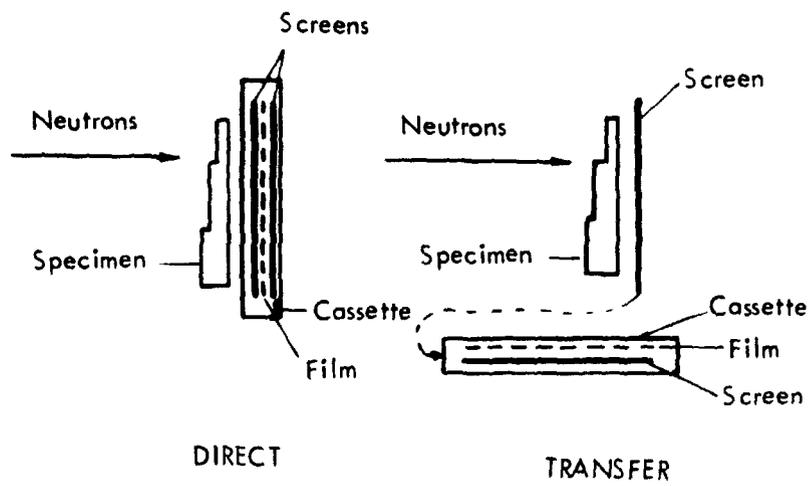
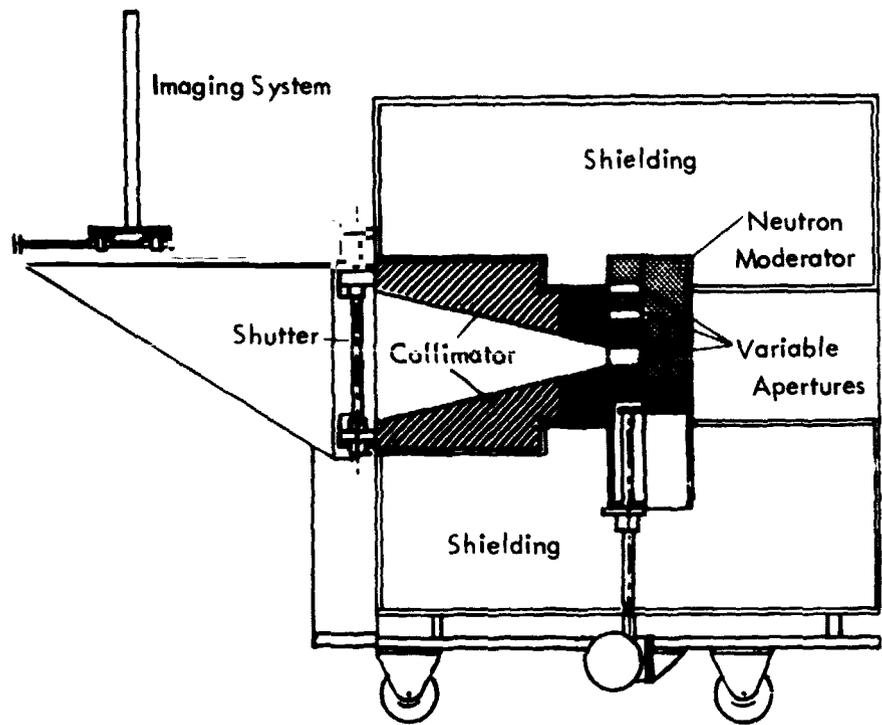


Figure 1-28. Diagram of a Portable Neutron Radiography Facility and Types of Film Imaging

1.5.7 Microwave Method

1.5.7.1 Description - The microwave method uses electromagnetic (EM) energy as the probing media and the test can be arranged in either the reflection or through-transmission techniques. A third technique which senses scattered reflections is a hybrid of the above techniques. The method can only be used to evaluate nonmetallic materials in which changes in the material's dielectric constant and/or loss tangent can signal either geometric defects or property variations. The EM energy reflects from conductive metallic surfaces, so that a smooth metal plate or surface serves very well as a reflector in the reflection technique.

The microwave method is applicable to inspection of the Shuttle's solid rocket motor propellant, and the Orbiter's external thermal insulation (TPS). Internal separations and cracks in the PBAN and moisture absorption in the TPS are examples.

Defects normally detectable by this method are internal voids and porosity, delaminations, cracks, internal separations, adhesive voids and metallic inclusions. It is also a very sensitive responder to absorbed moisture in nonmetallic materials. The sensitivity of the method depends greatly on the magnitude of phase changes produced in the EM wave by relative dielectric variations or the magnitude of amplitude changes due to relative variations in dielectric loss tangent. Unwanted material variable affects can often be minimized in the microwave response by adjustment of certain system components.

The frequency of the electromagnetic energy is important from the standpoint of resolution and penetration power. The most commonly used range is from 8 to 12 GHz (Billion cps), but may range up to 60 GHz. Table 7 gives the letter designations of the microwave frequency bands. The higher the frequency, the better the resolution for detecting small voids, porosity, and inclusions. But, since the loss tangent generally increases with frequency for most materials, the penetration declines. This has both advantages and disadvantages. For instance, thick sections of a solid rocket motor PBAN material may very seriously attenuate a 40 GHz

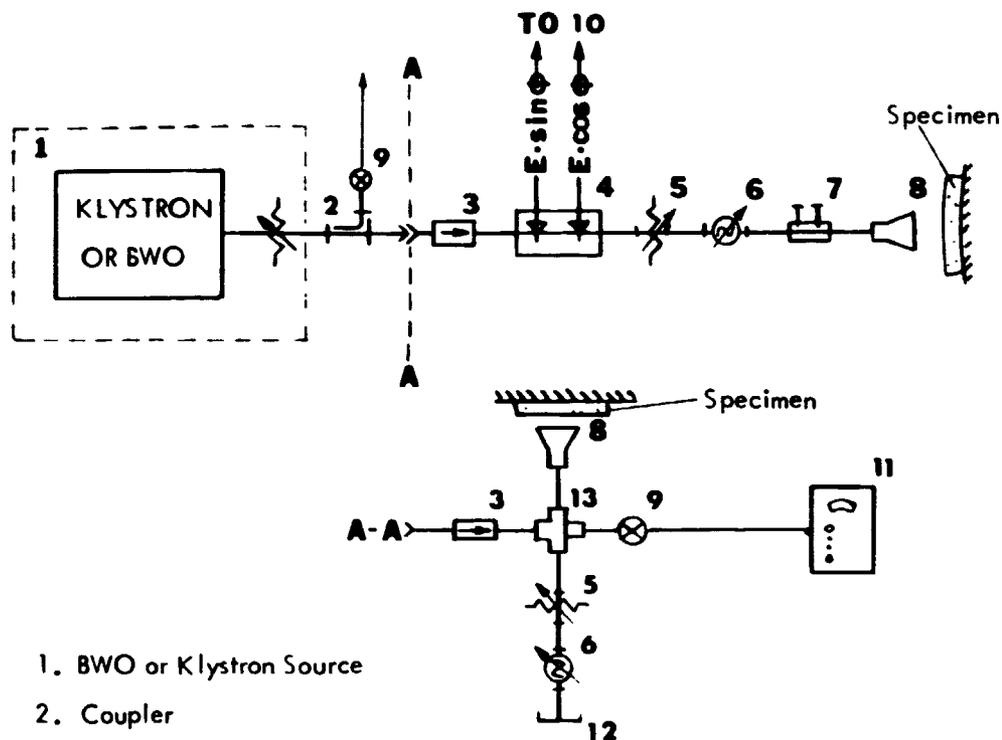
TABLE 7. LETTER DESIGNATIONS AND VACUO WAVELENGTH RANGE OF MAJOR BANDS OF THE MICROWAVE SPECTRUM

LETTER	FREQUENCY BAND, GHz	WAVELENGTH RANGE (VACUO), cm
L	0.390 to 1.550	76.9 to 19.3
S	1.550 to 5.200	19.3 to 5.77
X	5.200 to 10.900	5.77 to 2.75
K	10.900 to 36.000	2.75 to 0.834
Q	36.000 to 46.000	0.834 to 0.652
V	46.000 to 56.000	0.652 to 0.536
W	56.000 to 100.000	0.536 to 0.300

signal, whereas a 10 GHz signal will suffer considerably less attenuation, even though the resolution is greatly reduced. On the other hand the loss tangent of a contaminant, such as water, may increase faster with frequency than does the loss tangent of the base material, so that a higher frequency in this case would be desirable for differentiation.

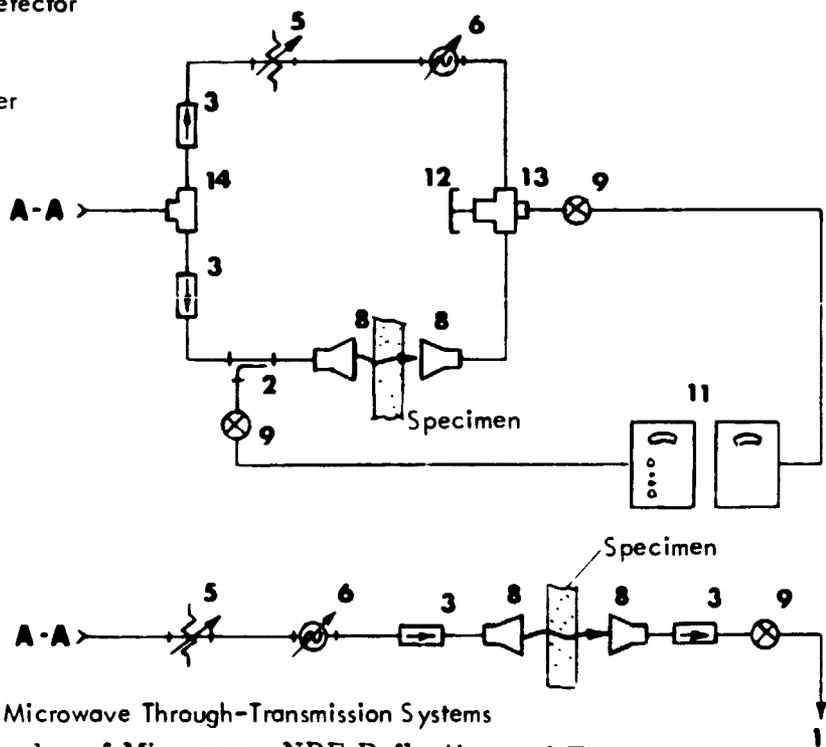
The choice of a probing frequency, therefore, is, assuming that instrumentation logistics is no problem, usually a compromise between desired resolution and adequate signal strength. The compromise rests greatly on the type and size of defects or property variations which are of interest to the inspection program. Knowing the type and sizes of defects that must be detected in the material and having on hand dielectric constant- and dielectric loss tangent - versus frequency charts for the materials, moisture, etc., are prerequisites for making an intelligent choice of frequency.

1.5.7.2 Microwave Systems and Equipment - A microwave system generally consists of a powered fixed-frequency klystron oscillator or backward-wave oscillator, phase changers, attenuators, waveguide, antennas (signal launches/receivers), detectors and a readout device. Other accessories such as waveguide tees, Hybrid or "magic" tees, waveguide sections such as bends, couplers, isolators, etc., may be needed in various test arrangements. Figure 1-29 illustrates the circuit arrangement of various microwave inspection systems. The klystron should be able to deliver 10-20 milliwatts (mv) of power, maximum, except for inspection of thick motor sections which may require considerably more power (several hundred milliwatts). The readout device can be a power meter or an X-Y recorder having a polar chart. The latter requires the use of a special waveguide detector called an impedance plotter which facilitates the separation of phase and amplitude information on the polar chart. The EM wave can either be pulsed or continuous. The use of a power meter or standing wave ratio meter as the readout device usually requires 1000-cycle square wave modulation of the EM wave. The effects of unwanted material variables can be suppressed by adjustment of attenuators and phase changers. These system components are also used to "zero" the system on the reference standard.



Microwave Reflectometer Systems

1. BWO or Klystron Source
2. Coupler
3. Isolator
4. Impedance Plotter Detector
5. Variable Attenuator
6. Variable Phase Shifter
7. Tuner
8. Waveguide Antenna
9. Crystal Detector
10. X-Y or Polar Plotter
11. Power or SWR Meter
12. Tuneable Short
13. Hybrid (Magic) Tee
14. Waveguide Tee
15. Reflector



Microwave Through-Transmission Systems

Figure 1-29. Examples of Microwave NDE Reflection and Through-Transmission Systems

The equipment can be arranged either as a reflectometer system or as a through-transmission system. With sufficient microwave waveguide components on hand any of the illustrated systems can be arranged. Adequate standards representing material, geometry, configuration (e.g., material on substrate) and defects must be available.

1.5.7.3 Microwave Moisture Analysis. The free (unbound) moisture content of the Orbiter's silica RSI/TPS can be accurately assessed with microwave techniques because of the high dielectric constants of the water molecule relative to the silica material. The microwave energy will be strongly absorbed or scattered by the moisture infused into the transparent TPS tile. The dielectric properties of water is a function of temperature, however, so that moisture analysis should be accomplished within a certain range of TPS temperatures. For the installed TPS, the microwave moisture meter can be applied as a reflectometer, with the energy passing through the material, reflecting from the metal skin and returning through the material to the transmitter - or as a pitch-catch instrument in which the energy is launched by a transmitter antenna having an angular incidence to the TPS surface, reflected off the top layer of material, and sensed by a receiver antenna. In either test mode, the antennas are kept at the same distance while scanning the TPS panel. If moisture is encountered, the instrument will register a sharp change in readout relative to a dry region.

1.5.8 Thermographic Method

1.5.8.1 Description - This section will briefly describe three thermal methods that are applicable to NDE of metallic honeycomb structures for detection of near-side bonds between facesheet and core or doubler and facesheet. The methods are also applicable to bonded metal-metal laminates. Such composite structures are located on the Shuttle Orbiter's elevon, rudder/speed brake, aft body flap, and thrust structure/boron doublers, and also on the SRB aft fins.

The thermal methods may be used in lieu of the sonic or ultrasonic techniques specified for honeycomb/laminate debond detection. The IR method is particularly suited to fulfill this function. Both groups of methods may be effective, providing the facesheet thickness is not too great, in which case the ultrasonic ringing technique is preferable. The major consideration in selecting from either group probably lies in their relative cost-effectiveness of actually applying the methods. Preparation of the structural inspection surfaces is the same for either group of NDE methods, which requires removal of the external thermal protection system (TPS) tiles in the inspection areas and thorough cleaning of the surfaces to remove all foreign (non-metal) materials.

Basically, thermal methods depend on either introducing heat into the material or taking advantage of internal heat sources, then sensing the patterns produced by differential heat flow across the surface of the part. The patterns are indicative of structural features, defects or thermal property variations. The methods are described below.

1.5.8.2 Infrared NDE - NDE by the infrared method, sometimes referred to as IR thermography, is performed by using a scanning radiometer or camera which senses radiant energy emitted from a surface by virtue of its temperature. IR detector systems are comprised of three basic elements: 1 input optical system, 2 infrared detector, and 3 signal processing and readout system. The optics collect and filter the incoming radiation and focuses it on the surface of the detector. The detector converts the IR

energy into a voltage which is transmitted to the signal processing circuits for amplification and conversion to a form suitable to the desired readout mode. The processed information can be displayed on a meter, strip-chart or C-scan recorder, storage oscilloscope, IR-sensitive film or a modulated-light photographic system.

The optics section of a scanning IR camera contains the scanning mechanism which, in turn, necessitates the signal processing circuits and readout display being synchronized with the input scanning operation. Modern IR cameras have evolved with greatly improved sensitivity and spectral response, rapid scanning optics, and multiple data presentation methods.

The IR method is based on the principle that every object emits heat at various intensities and wavelengths depending on the physical characterization of the material and its temperature. Under non-equilibrium conditions, heat flows through a part, producing varying temperatures along the surface. A defect or structural feature can disrupt or modify the flow of heat, which is revealed by the IR system. Heat can be introduced into the material by use of a heating blanket, heat lamp, forced air heater, or some other external means, or by residual heat due to solar energy absorption, operating equipment or interaction with the operating environment (re-entry). The IR system must be calibrated in order to give reproducible results. Radiometers are usually calibrated by referencing to an internal "black body" cavity so that output data can be provided on an absolute scale.

A practical system for IR NDE of Orbiter honeycomb materials would use a tripod camera containing the radiometer, amplifier and storage oscilloscope display. When desired, magnetic tape can provide a permanent record of defect conditions. Some attractive commercial IR systems that have potential use as Shuttle NDE systems include the ATA Thermovision Model 680, Barnes Engineering Model T-101, and the Dynarad Thermo-Imager Model 200.

IR NDE Procedure - (TBD)

1.5.8.3 Thermochromic Paints - These methods involve the use of strippable paints applied by painting, spraying or dipping. They produce temperature-dependent color changes upon activation. The inspection surface must be clean before applying the paint. The paint is allowed to dry for one to two hours, then activated with ultraviolet light which causes the paint to exhibit a purplish color. Heat is applied at about 52 degrees C which rapidly bleaches the coating to a whitish color. When the surface approaches 52°C, a purple and white pattern is produced so that, in the case of honeycomb inspection, a characteristic cross-hatched pattern is produced in the paint. Debonds are seen as distinctly missing portions of the pattern. The pattern, which is reversible, remains stable for several hours if not exposed to heat or excessively bright light, and the paint may be reactivated several times without appreciable loss of sensitivity. Debonds as small as 1/4-inch (6.35mm) in diameter have been reported.

1.5.8.4 Liquid Crystals - Liquid crystals, usually derivatives of cholesteric esters, offer a feasible method for inspection of some types of structure. These materials are optically active substances which exhibit transient color changes in response to temperature changes. Each liquid crystal derivative reacts in its own way to temperature changes, the important characteristic being that each color corresponds to a specific temperature. These materials are generally colorless on either side of the liquid crystal state, i.e., in the true solid and ultimate liquid crystal state. It is in the temperature transition region that the substances exhibit color changes.

Due to the ability of these substances to reflect colors dependent upon the environment temperature, they can be used to project a visual color picture of transient temperature distributions, or thermal gradients. The resulting color changes can reveal structural features and near-surface material flaws. For this reason they are applicable to brazed and bonded structures such as honeycomb composites to detect debonds and other internal defects. Titanium composites and

heat-resistant metals are suitable for testing with liquid crystals. Comparable structures made of aluminum alloys are not as suitable because of the rapid dissipation of the surface thermal gradients.

The major problem associated with use of liquid crystals lies in the difficulty of establishing and maintaining a suitable thermal pattern for a sufficient time to assess the structure. The highly transient nature of the thermal gradients makes inspection with this method difficult for materials of high thermal conductivity.

The technique requires cyclical heating and cooling of the inspected structure by applying and withdrawing an external heat source. This process presents impractical difficulties for materials of either very high or low thermal conductivity but works suitable on those of intermediate conductivity.

1.6 NDE Equipment

The equipment and facilities necessary to provide a sufficient nondestructive evaluation capability cannot be defined specifically and thoroughly until all detailed NDE procedures for structure, components and TPS inspection have been developed. Areas where further laboratory development is required such as the TPS, will define additional NDE equipment and materials, some of which perhaps cannot be anticipated at this time.

An Inspection Material and Equipment List is provided in Table 8, however, which - with the exception of the thermal, microwave, gamma- and neutron-radiography equipment - characterizes a complete inventory for a typical large air transport. The list, accounting for the exceptions given, corresponds to that sufficient to inspect the C-5A airplane in accordance with AF T.O. 1C-5A-36. Some listings are made for the thermal, microwave, gamma- and neutron-radiographic methods, but these are not to be considered as recommended models at this time since such recommendations must be specified in developed NDE procedures.

The provided list should be considered for reference and planning purposes only and should not be used at this time for stocking inventories.

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG
A. OPTICAL	Flexible Fiber Optic Insp. Instrument	Fiberscope	American Optical
	Borescope (Rigid)	B-27A	American Cysto- scope
	Borescope & Endo- scope Photography	Nikon	National Statham Inc.
	Optical Magnifier, Comparators		Bausch & Lomb
	Flexible & Rigid Inspectoscopes	Ederscope	Eder Instrument Company
B. PENETRANT	Solvent - Removal Fluorescent Penetrant	Type I, Group VII ZL22A	Magnaflux
	Fluorescent Penetrant Kit, Consisting of: Certified Chlorine- Free Cleaner Fluorescent Pene- trant Developer	ZC-7 ZL22A 2P-9	Magnaflux
	Material Replace- ment Kit	ZY-1RA	Magnaflux
	Penetrant, Post Emulsifiable	Type I, Group V ZL-2A, Type I, Group VI ZL-22A	Magnaflux
	Emulsifier, Oil Base	ZE-3	Magnaflux
	Developer, Wet	ZP-5	Magnaflux
	Black Light		Magnaflux
	Black Light, Portable Flash- light, Non- Explosive		

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
C. MAGNETIC PARTICLE	Magnetic Inspection Unit, Portable Hand Probe	DA-200	Parker Research
	Inspection Unit, Portable, 750 Amps	KH07	Magnaflux
	Inspection Unit, Portable 3000 Amps	KCH-3D	Magnaflux
	Fluorescent Magnetic Particle Suspension Demagnetization Coil		Magnaflux
	Field Indicator, Magnetic Variation, 0-6 Oersteds	105645	Magnaflux
	Magnetic Rubber		Dynamold, Inc.
	D. EDDY CURRENT	Crack, Detector	ED-520
Conductivity Meter		NDT-5	Nortec
Crack Detector with 500 kHz Module		NDT-3	Nortec
Adapter, (Between Series) UHF to BNC		UG-255/u	Amphenol
Adapter and Cable		R-100	Nortec
Cable, Microdot/ BNC Connector		3090	Nortec
Draftsman Circle Template		No. 140	
Calibration Standard Aluminum, Figure 1-19-0			Local Manufacture
Calibration Standard, Steel, Figure 1-19-0			Local Manufacture

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
D. EDDY CURRENT (CONT)	Calibration Standard, Titanium, Figure 1-19-0		Local Manufacture
	Probe, General Purpose 1/8-Inch Diameter	201218	Magnaflux
	Probe, General Purpose 1/4-Inch Diameter	200634	Magnaflux
	Probe, General Purpose 3/8-Inch Diameter	62743	Magnaflux
	Probe, General Purpose 1/8-Inch Diameter	6100-1/8-S	Ideal Specialties
	Probe, Surface	SP-500	Nortec
	Probe, Surface 1/8-Inch Radius, 500 kHz	PP-16	Nortec
	Probe, Surface Pencil 1/8-Inch Radius, 500 kHz	PP-16	Nortec
	Probe, Surface Pencil Flat Tip, 500 kHz	FPP-16	Nortec
	Probe, Surface, 1/4-Inch Diameter x 1.00-Inch Long	6100-1/4 x 1.00-S	Ideal Specialties
	Probe, Miniature General Purpose, 5/16-Inch Dia. x 1 1/8 Inch Long	205155	Magnaflux

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
D. EDDY CURRENT (CONT)	Probe, 1/4-Inch Radius Freq. A (Modified) Complete with Amphenol P/N UG255/U, UHF to BNC Adaptor	Model MP	Dermitron
	Probe, 45 Degree Angle 5/16-Inch Diameter	62742	Magnaflux
	Probe, Right Angle, Freq. A Complete with Amphenol P/N UG255/U, UHF to BNC Adaptor	Model RP	Dermitron
	Probe, Right Angle, 1/8-Inch Diameter (Dimension A, 0.25 Inch)	210178 (See Figure 1-18-0)	Magnaflux or (Local Purchase)
	Probe, Right Angle, 1/8-Inch Diameter Various Tip Lengths	210179 (See Figure 1-18-0)	Magnaflux or (Local Purchase)
	Probe, Bolt Hole, 1/8-Inch Diameter, x 1.00-Inch Long	6200-1/8 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 5/32-Inch Diameter x 1.00-Inch Long	6200-5/32 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 3/16-Inch Diameter	207362	Magnaflux
	Probe, Bolt Hole, 3/16-Inch Diameter, 500 kHz	BP-12	Nortec
	Probe, Bolt Hole, 3/16 to 1/4-Inch Dia. x 1.00-Inch Long	6200-3/16 to 1/4 x 1.00 BH	Ideal Specialties

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
D. EDDY CURRENT (CONT)	Probe, Bolt Hole, 1/4-Inch Diameter, 500 kHz	BP-16	Nortec
	Probe, Bolt Hole, 1/4-Inch Diameter x 1.00-Inch Long	6200-1/4 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 1.4 to 5/16-Inch Diameter	201427	Magnaflux
	Probe, Bolt Hole, 5/16-Inch Diameter, 500 kHz	BP-20	Nortec
	Probe, Bolt Hole, 5/16-Inch Diameter x 1.00-Inch Long	6200-5/16 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 5/16 to 3/8-Inch Diameter	201428	Magnaflux
	Probe, Bolt Hole, 3/8-Inch Diameter, 500 kHz	BP-24	Nortec
	Probe, Bolt Hole, 3/8-Inch Diameter x 1.00-Inch Long	6200-3/8 x 1.00	Ideal Specialties
	Probe, Bolt Hole. 3/8 to 1/2-Inch Diameter	200852	Magnaflux
	Probe, Bolt Hole, 7/16-Inch Diameter, 500 kHz	BP-28	Nortec
	Probe, Bolt Hole, 7/16-Inch Diameter x 1.00-Inch Long	6200-7/16 x 1.00 BH	Ideal Specialties

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/SPECIFICATION	MFG.
D. EDDY CURRENT (CONT)	Probe, Bolt Hole, 1/2-Inch Diameter, 500 kHz	BP-32	Nortec
	Probe, Bolt Hole, 1/2-Inch Diameter x 1.00-Inch Long	6200-1/2 x 1.00	Ideal Specialties
	Probe, Bolt Hole 1/2 to 11/16-Inch Diameter	200853	Magnaflux
	Probe, Bolt Hole, 9/16-Inch Diameter, 500 kHz	BP-36	Nortec
	Probe, Bolt Hole, 9/16-Inch Diameter x 1.00-Inch Long	6200-9/16 x 1.00	Ideal Specialties
	Probe, Bolt Hole, 5/8-Inch Diameter, 500 kHz	BP-40	Nortec
	Probe, Bolt Hole, 5/8-Inch Diameter x 1.00-Inch Long	6200-5/8 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 11/16-Inch Diameter x 1.00-Inch Long	6200-11/16 x 1.00	Ideal Specialties
	Probe, Bolt Hole, 11/16 to 1 1/6 Inch Diameter	200854	Magnaflux
	Probe, Bolt Hole, 3/4-Inch Diameter, 500 kHz	BP-48	Nortec
	Probe, Bolt Hole, 3/4-Inch Diameter x 1.00-Inch Long	6200-3/4 x 1.00	Ideal Specialties

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/SPECIFICATION	MFG.
D. EDDY CURRENT (CONT)	Probe, Bolt Hole, 13/16-Inch Diameter x 1.00-Inch Long	6200-13/16 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 7/8-Inch Diameter, 500 kHz	BP-56	Nortec
	Probe, Bolt Hole, 7/8-Inch Diameter x 1.00-Inch Long	6200-7/8 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 15/16-Inch Diameter x 1.00-Inch Long	6200-15/16 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole, 1-Inch Diameter, 500 kHz	BP-64	Nortec
	Probe, Bolt Hole, 1.00-Inch Diameter x 1.00-Inch Long	6200-1.00 x 1.00 BH	Ideal Specialties
	Probe, Bolt Hole 1 to 1 1/4 Inch Diameter	208743	Magnaflux
	Probe, Bolt Hole, 1 1/6 Inch Diameter x 1.00-Inch Long	6200-1 1/16 x 1.00 BH	Ideal Specialties
E. ULTRASONIC	Reflectoscope	UM-715	Sperry
	Video Plug-In Module, 1N	50E534	Sperry
	Video Plug-In Module, 10N	50E533	Sperry
	Video Plug-In Board, 15.0 mHz	50B955	Sperry
	Ultrasonic Caliper	Sonoray	Branson
	Video Plug-In Module, HFN	50E527	Sperry

TABLE 8. INSPECTION MATERIAL AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
E. ULTRASONIC (CONT)	Cable, 6 foot, Microdot/UHF Connector	57A2270	Sperry
	Cable, 6 foot, Microdot/BNC Connector	57A2271	Sperry
	Cable, 6 foot, 90-degree Microdot/UHF Connector	57A4487	Sperry
	Calibration Standards, Various		Local Manufacture
	Transducer, 1.0 mHz, 0.500-Inch Diameter, Longitudinal Wave	57A2439	Sperry
	Transducer, 1.0 mHz, 0.500-Inch Diameter, Longitudinal Wave, Shuntless	57A2439	Sperry
	Transducer, 2.25 mHz, 0.312-Inch Diameter, Longitu- dinal Wave	57A2274	Sperry
	Transducer, 2.25 mHz, 0.312-Inch Diameter, Longitu- dinal Wave, Shuntless	57A2274	Sperry
	Transducer, 5.0 mHz, 0.187-Inch Diameter, Longitu- dinal Wave	57A2284	Sperry
	Transducer, 5.0 mHz, 0.187-Inch Diameter, Longitu- dinal Wave, Shuntless	57A2284	Sperry

TABLE 8. INSPECTION MATERIALS AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
E. ULTRASONIC (CONT)	Transducer, 5.0 mHz, 0.187-Inch Diameter, Longitu- dinal Wave, Modified Note: Height not to exceed 0.250- inch	57A2284 Modified	Sperry
	Transducer, 5.0 mHz, 0.187-Inch Diameter, Longitu- dinal Wave, Top Connector	57A9454	Sperry
	Transducer, 5.0 mHz, 0.250-Inch Diameter, Longitudinal Wave	57A2214	Sperry
	Transducer, 5.0 mHz, 0.250-Inch Diameter, Longitudinal Wave, Shuntless	57A2214	Sperry
	Transducer, 5.0 mHz, 0.250-Inch Diameter, Longitudinal Wave, Type SCJ	J160	Sperry
	Transducer, 5.0 mHz, 0.312-Inch Diameter, Longitudinal Wave, Shuntless	57A2215	Sperry
	Transducer, 10.0 mHz, 0.187-Inch Diameter, Longitudinal Wave	57A2278	Sperry

TABLE 8. INSPECTION MATERIALS AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
E. ULTRASONIC (CONT)	Transducer, 10.0 mHz, 0.250-Inch Diameter, Longitu- dinal Wave	57A2279	Sperry
	Transducer, 10.0 mHz, SCJ, 0.250- Inch Diameter, Longitudinal Wave, Side Connector	J536	Sperry
	Transducer, 15.0 mHz, SIL, 0.250- Inch Diameter, Longitudinal Wave, Side Connector	57A8071	Sperry
	Transducer, 2.25 mHz, 0.250 x 0.250, 45 degree, Steel, Shear Wave, Top Connector	57A3043TC	Sperry
	Special Transducer, 5.0 mHz, 0.187 x 0.187, 45 degree, Shear Wave, Top Connector	57A9466	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 45 degree Aluminum, Shear Wave	57A3064	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 45 degree, Aluminum, Shear Wave Front Connector	57A3064 (Front Connector)	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 45 degree, Steel, Shear Wave	57A3052	Sperry

TABLE 8. INSPECTION MATERIALS AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
E. ULTRASONIC (CONT)	Transducer, 5.0 mHz, 0.250 x 0.250, 45 degree, Steel, Shear Wave, Side Connector	57A3052 (Side Connector)	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 45 degree, Steel, Shear Wave, Top Connector	57A8299	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 60 degree, Aluminum, Shear Wave	57A3065	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 60 degree, Steel, Shear Wave	57A3053	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 60 degree, Steel, Shear Wave, Top Connector	57A3053TC NOTE: Same as 57A8300	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 60 degree, Steel, Shear Wave, Top Connector	57A8300 NOTE: Same as 57A3053TC	Sperry
	Transducer, 50 mHz, 0.187 x 0.187, 48 degree, Aluminum, Shear Wave, Top Connector	57A8790	Sperry

TABLE 8. INSPECTION MATERIALS AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/ SPECIFICATION	MFG.
E. ULTRASONIC (CONT)	Transducer, 5.0 mHz, 0.187 x 0.125, 70 degree, Shear Wave, Top Connector (Case dimensions approxi- mately 0.300 wide, 0.400 long, 0.300 height)	57A9470	Sperry
	Transducer, 5.0 mHz, 0.250 x 0.250, 70 degree, Aluminum Shear Wave, Side Connector	57A3066 (Side Connector)	Sperry
F. RADIO- GRAPHIC	X-ray Machine, Portable, 160 KVP, 40 degree Tube Head	SPX-160E-8-C	Sperry
	X-ray Machine, Mobile 275 KVP, 35 degree Tube Head	SPX-65D119-275 KV, 10 MA	Sperry
	Tube Head, 360 degree, 275 KVP		Sperry
	Tube Head, 360 degree, 160 KVP		Sperry
	Film	Various	Various
	Film Processing Unit		Eastman
	Neutron-Radio- graphic Camera, Truck Mounted	CFNR-10 or CFX	Intel Com Rad
	Neutron Source	252Cf, Californium	Intel Com Rad

TABLE 8. INSPECTION MATERIALS AND EQUIPMENT LIST
(CONT)

TYPE INSPECTION	DESCRIPTION	PART NO./TYPE/SPECIFICATION	MFG.
F. RADIO-GRAPHIC (CONT)	Converter Screens	Gadolinium Foil	Intel Com Rad Tech
	Gamma Ray Source	^{192}Ir , Iridium	AEC
		^{170}Tl , Thulium	AEC
	Source Capsule		AEC
	Source Storage Containers		
	Source Handling Tools (Manual, Pole, Cable-Drive, Pneumatic Drive)		
G. THERMAL	Infrared Scanner	Model 680	AGA Thermouision
	Infrared Scanner	Model 200 Thermo-Imager	Dyna-Rad
	Scope Camera		Polaroid
	Magnetic Tape Recorder		
	Forced Air Heater		
	Thermal Paint		
H. MICROWAVE	Microwave Moisture Gage	Model 631A	Microwave Instruments Company
	Microwave Interferometer System		
	Microwave Reflectometer System		
	X-Y Recorder		Esterline Angus
	Power Meter		Hewlett Packard

1.7 Safety Precautions in Using NDE Equipment

WARNING

Electrical equipment shall not be operated in areas where combustible gases or vapors may be present, unless the equipment is explosion-proof. Failure to observe this precaution may result in injury or death to personnel and damage to the vehicle.

1.7.1 Safety Requirements for Use of Penetrants

The following considerations must be observed when performing penetrant inspection procedures:

- a. Use adequate ventilation while handling cleaners, emulsifiers, penetrants, or developers. Prolonged or repeated inhalation of vapors or powders may cause irritation of mucous membrane areas of the human body.
- b. Avoid contact with penetrant inspection materials. Continual exposure to penetrant materials may cause skin irritation.
 - (1) Wear neoprene gloves and keep insides of gloves clean.
 - (2) Wash exposed areas of body with soap and water.
 - (3) Check for fluorescent penetrants on skin, clothes, and gloves with black light.
- c. Follow the manufacturer's instructions when using black light sources, and filter all light sources requiring filtering. Unless no filter is required, unfiltered light sources may damage the eyes.

- d. Store all pressurized spray cans in a cool dry area protected from direct sunlight. Do not use cleaning compounds near open flames or high heat sources nor place any pressurized can near such sources. Temperatures in excess of 120°F may cause the can to burst and injure personnel.
- e. Avoid heating of penetrants to the point where certain lighter constituents are released. Volatile fumes may occur, creating both a fire and health hazard.

1.7.2 Safety Requirements for Use of Magnetic Particles

The following precautions must be observed during magnetic particle inspection.

- a. If the part being inspected is high heat treat steel, the cleaning solvents used must be only those specified for high heat treat steel.
- b. Keep cleaning fluids and magnetic particles out of areas where they could become entrapped.
- c. Dissimilar metals such as bearings, bushings, and inserts must be removed prior to cleaning and inspection.
- d. Do not magnetize bearings.
- e. Arcing caused by poor contact or excessive current between instrument heads could damage the part and may be hazardous to humans.
- f. Prolonged handling of pastes and cleaners could cause irritation of the skin.

1.7.3 Safety Requirements for Use of Eddy Current

Under normal conditions, the use of eddy current equipment does not require special safety precautions other than the WARNING given in the paragraph headed SAFETY PRECAUTIONS.

1.7.4 Safety Requirements for Use of Ultrasonics

The following precautions must be observed when performing ultrasonic inspection.

- a. Observe warning about explosion-proof equipment given under "Safety Precautions."
- b. Ground instrument to airplane structure and use a grounded power cord.
- c. Turn power OFF before connecting or disconnecting cable to transducer.

1.7.5 Safety Requirements for Use of X-Rays and Gamma Rays

The use of X-rays and Gamma Rays in nondestructive inspection presents a potential hazard to operating and adjacent personnel, unless all safety precautions and protective requirements are observed. The use of X-ray and Gamma-ray sources must be in accordance with Federal, State, and Local Radiation Safety Laws.

- a. See NASA CR-61213 for safe limits of exposure. Exposure to excessive radiation is harmful to human beings.
- b. Personnel must keep outside the useful radiation beam at all times. The most effective protection while radiation equipment is in use is distance.
- c. Establish the hazardous area with a survey meter and post the area with radiation warning signs.
- d. Do not operate radiation equipment in area where combustible gasses or vapor may be present.
- e. When gamma-ray sources are not in use, they must be kept in proper lead containers during storage or transporting.

- f. Radioactive materials must never be handled directly. Use proper handling equipment when removing or replacing source in container and positioning for test.
- g. Any person receiving a radiation dose in excess of specified safe limitations as indicated by a dosimeter or otherwise shall be cause to stop all operations immediately and report the incident, all related facts, and personnel identification to the Medical Department and the Safety Officer.

1.7.6 Safety Requirements for Use of Neutron Radiography

The use of neutrons in nondestructive inspection presents certain safety hazards to operating and adjacent personnel. All safety precautions and protective requirements must be observed. The use of radioactive materials must always be in accordance with Federal, State, and Local Radiation Safety Laws.

- a. Generally, the same safety precautions are to be used as in applicable to X-ray and Gamma-ray radiation.
- b. Proper distance and shielding of personnel from the radioactive source must be maintained at all times during source transport, storage and deployment.

1.7.7 Safety Requirements for the Use of Thermography

The following precautions must be observed when using thermographic methods.

- a. Heat sources must be used so as not to cause injury to personnel or damage to airframe materials and components.
- b. Do not use open heat sources such as filaments and forced air heaters in explosive environments. Use only heat sources approved and recommended by the maintenance/safety officer.

- c. Thermographic paints or liquid crystal substances should be thoroughly removed from the airframe materials with approved cleaning procedures after the inspection. Use care that these materials are applied only to the surface of the part being inspected and are not allowed to contaminate joints, faying surfaces, emissivity surfaces, mechanisms and the like.

1.7.8 Safety Requirements for the Use of Microwave Methods

The following precautions are to be observed when performing microwave inspection.

- a. Microwave energy at power levels normally encountered in microwave inspections are not sufficient to cause injury to personnel or damage to materials.
- b. Microwave radiation can interfere with microwave communications, navigation, and ground control approach equipment. Be sure that test areas are sufficiently shielded or that a test frequency has been selected that will not interfere with local microwave equipment.
- c. High voltages encountered in microwave sources must not be allowed to become hazardous to operating personnel or explosive environments.
- d. During inspection of the Thermal Protection System insulation use extreme care to prevent damaging the emissivity surfaces with the microwave equipment, test fixtures or personnel.

1.7.9 NDE Material Residues

Some NDE techniques may result in leaving a residue on the structural components to which they are applied. These techniques primarily include the penetrant,

magnetic particle and ultrasonic methods. The residues are potentially harmful in producing corrosion, hydrogen embrittlement, breakdown or contamination of surface finish, and - very importantly - the contamination of the crew module atmosphere. The residue media may include cleaning compounds, penetrant/emulsifier/developer materials, magnetic particles, coupling compounds for ultrasound, and any other liquid, paste or powder which may be used in preparation for or application of the NDE techniques. Care must be used not only in the selection of all such materials to be used, but in the application of them and in post-inspection cleaning practices.

a. Material Selection Considerations

- o use only sulphur-free and chlorine-free ion penetrant inspection materials on titanium parts and fasteners
- o use nonchlorinated or alkaline cleaning solvents on titanium
- o do not use acid-base cleaners and solvents on high-strength steels, or hydrogen embrittlement may result
- o use evaporable or water washable materials when possible.

b. Material Application Considerations

- o do not use excessive amounts of the materials and confine their application strictly to the area being cleaned or inspected
- o do not permit the materials to be drawn into tight interface or openings by capillary attraction
- o confine application to smooth, monolithic surfaces to the extent possible
- o do not permit cleaning or inspection materials to be ingested in any way in the spacecraft environmental control system.

c. Pre-cleaning or Post-cleaning Operations

- o use only certified safe cleaning materials for the specific structural materials being inspected

- o confine cleaning materials to the specific areas to be inspected
- o remove penetrant, particles, and acoustic coupling compounds as completely as possible
- o when cleaning solvents, coupling compounds, or penetrant materials are used in the crew module, extreme care must be exercised to thoroughly remove by cleaning, wiping and/or purging all residues that may contaminate the module atmosphere
- o safe heat sources may be useful for drying residues trapped in holes or inaccessible places.

1.8 Acceptance/Rejection

Only trained and certified nondestructive test personnel are permitted to apply NDE techniques to assess the integrity of airframe structure, external insulation or systems in order to preclude inadequate inspection, erroneous results, or injury to personnel. Unskilled personnel should not attempt to interpret nondestructive test results. To do so may result in erroneous acceptance or rejection decisions.

When structural damage is suspected as a result of applying an NDE technique, the damage should be verified by applying a second technique differing from the first when possible, or using the same technique applied by a different skilled operator. The results of all applied NDE should be documented for acceptance/rejection review.

When it is determined that damage probably exists in a critical area, these results should be reported immediately to the Responsible Activity for decision and action.

1.9 References

Documents other than design drawings used or referenced in this manual are:

1. "Fracture Control Design Methods", NASA Contract NAS 3-16765, Progress Reports 73MA1935 (9 Apr 1973), 73MA5769 (31 Oct 1973) and 73MA5939 (15 Nov 1973).
2. "Requirements/Definition Document (Space Shuttle), Structures, Book 1", NASA Contract NAS 9-14000, Rockwell International Space Division Report SD72-SH-0101.
3. T.O. 1C-5A-36, "C-5A Nondestructive Inspection Manual", USAF, Lockheed-Georgia Company, 1973.
4. "DC-10 Nondestructive Testing Manual", McDonnell Douglas Corporation, 1971.
5. "L-1011 TriStar Nondestructive Testing Manual", Lockheed-California Company, 1972.
6. "Quality Assurance. Guidance to Nondestructive Testing Techniques", 29 April 1970, AMCP 702-10, U. S. Army Material Command.
7. "Nondestructive Testing - A Survey", 8 April 1969, NASA SP-5113.

SECTION 2 - FORWARD FUSELAGE STRUCTURE

This section contains the NDE requirements for the crew module, upper and lower forward fuselage shell, nose landing gear and wheel well, forward RCS module, forward ET/ORBITER attach, and the forward fuselage aft bulkhead.

SECTION 2
TABLE OF CONTENTS

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
2-101	Cabin-Fus Shell Support Link and Bracket Assembly	2-1
2-102	Fwd Fuselage Frame Caps	2-4
2-103	Forward Fuselage Skins	2-6
2-104	Window Frames, Fuselage Shell	2-8
2-201	NLG Drag Link Support Fitting	2-10
2-202	NLG Trunnion Support Fitting	2-11
2-203	NLG Axle	2-13
2-204	NLG Shock Strut Piston	2-14
2-205	NLG Shock Strut Main Cylinder	2-15
2-206	NLG Torque Links	2-16
2-207	NLG Lower Drag Brace	2-17
2-208	NLG Upper Drag Brace	2-18
2-209	NLG Lower Down-Lock Brace	2-19
2-210	NLG Upper Down-Lock Brace	2-20
2-211	NLG Drag Brace Cross Tie	2-21
2-212	Fwd ET/Orbiter Attach Point	2-23
2-213	Fwd RCS Module Structural Attachment Areas	2-25
2-214	Crew Module Entrance Hatch Opening	2-27
2-301	Cabin Fwd Bulkhead	2-29
2-302	Crew Module Window Frames	2-31
2-303	Cabin Canopy Panels (Above Z _o 419)	2-33
2-304	Cabin Mfg. Access Panel	2-35
2-305	Cabin Floor - Bulkhead Beams	2-37
2-306	Cabin Skin Panels (Below Z _o 419)	2-39
2-307	Cabin Aft Bulkhead	2-41

SECTION 2
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
2-1	Cabin-Fuselage Shell Support Link and Bracket Assembly	2-3
2-2	Forward Fuselage Frame Caps	2-5
2-3	Forward Fuselage Skins	2-7
2-4	Window Frames, Fuselage Shell	2-9
2-5	NLG Drag Link Support and Trunnion Support Fittings	2-12
2-6	Nose Landing Gear Assembly	2-22
2-7	Forward ET/Orbiter Attach Fitting	2-24
2-8	Forward RCS Module Structural Attachment Areas	2-26
2-9	Crew Module Entrance Hatch	2-28
2-10	Cabin Forward Bulkhead	2-30
2-11	Crew Cabin Window Frames	2-32
2-12	Cabin Canopy Panels	2-34
2-13	Cabin Manufacturing Access Panels	2-36
2-14	Cabin Floor/Bulkhead Beams	2-38
2-15	Cabin Skin Panels	2-40
2-16	Cabin Aft Bulkhead	2-42

PROCEDURE NO. 2-101, Figure 2-1

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, (X) POSTFLIGHT
ZONES 1, 2, & 3

SUBASSEMBLY: FWD FUS - CREW CABIN SUPT

DRAWING(S): VL70-001042

COMPONENT/AREA DESCRIPTION: CABIN-FUS SHELL SUPPORT LINK AND BRACKET ASSY: Ten titanium 6Al-4V link assemblies are situated along the upper and lower floor longerons on the left side and eleven on the right side of the fwd fus (21 fittings total). The link assembly consists of an eye-bolt and threaded sleeve which connects to a bearing lug bracket fitting on each of the forward fuselage shell and the cabin, helping to stabilize the floating crew cabin. The machined plate assembly has a safe-life design and receives both compressive and tensile flight loads (high-q boost, cabin pressurization). The locations for these components are: upper: Z_o 419; X_o 549, 522, 495, 469 and 441 (rt side only); lower: Z_o 326; X_o 564, X_o 537, X_o 510, X_o 483; X_o 456 and X_o 413 on left - and right-hand sides of the fwd fuselage.

DEFECTS: Link Assembly: Radial cracks may occur in the bearing lugs, or circumferential edge cracks in the eyebolt shaft near the thread run-out; Bracket Fittings: Radial cracks in the bearing hole lug and edge cracks near the lug-to-base transition on upper and lower sides of the bracket. Secondary cracks may occur in fastener holes in the aluminum frame cap, running fore-aft.

ACCESS: Attained by removing access plates near each of the 21 link assemblies, in the fwd fus outer skin panels. The thread runout can be inspected effectively only by removing the threaded fitting.

NDT TECHNIQUES: Primary: Ultrasonic shear wave for bearing lugs (see para. 1.5.5.3D) fluorescent penetrant for shaft/transition areas, the thread root areas and the cabin and fuselage bracket fittings (see para 1.5.2.1 Figure 1-9).

NOTE: In the event that access is severely restricted, built-in ultrasonic or fiber optics may provide more appropriate inspection.

BACKUP: Fluorescent penetrant of lugs after disassembly if necessary (see para. 1.5.2.1 Figure 1-9)

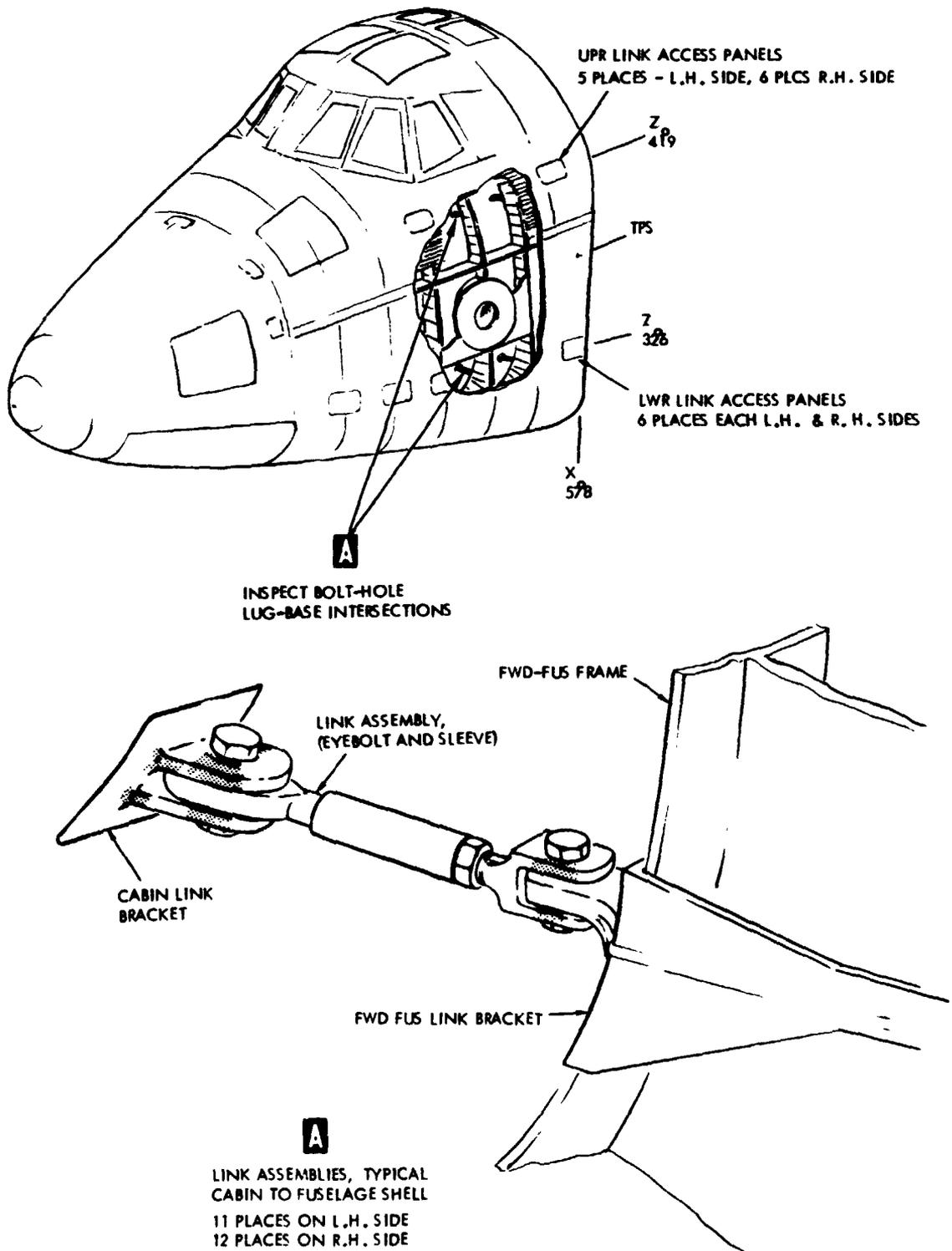


Figure 2-1. Cabin-Fuselage Shell Support Link and Bracket Assembly

PROCEDURE NO. 2-102, Figure 2-2

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE ZONES 1 & 2 TYPE INSPECTION (X) POSTFLIGHT

SUBASSEMBLY: FWD FUS SHELL

DRAWING(S): VL 70-001042 'A'

COMPONENT/AREA DESCRIPTION: FWD FUS FRAME CAPS: The fwd fuselage caps are made of 2024-8511 aluminum alloy extrusions and are coated with zinc chromate primer and Supercorapon 515-700 paint. They experience tensile stresses due to flight loads. The frame caps may experience fatigue damage at fastener attachments in the vicinity of the crew entrance hatch, fwd fus outer shell longitudinal splice, at crew cabin/fwd fus link assembly attachments and runouts near window frame sills and structure penetrations.

DEFECTS: Horizontal cracks at fastener holes.

ACCESS: Access is limited because frames are between crew cabin and outer fwd fus skins. Avionics and other equipment inside the crew cabin and TPS on outer skin further reduce access.

NDT TECHNIQUES: Primary: Radiography, fiber optics (see paragraph 1.5.6.2 and 1.5.1.3, respectively).

Backup: fiber optics (for radiography) (see para. 1.5.1.3).

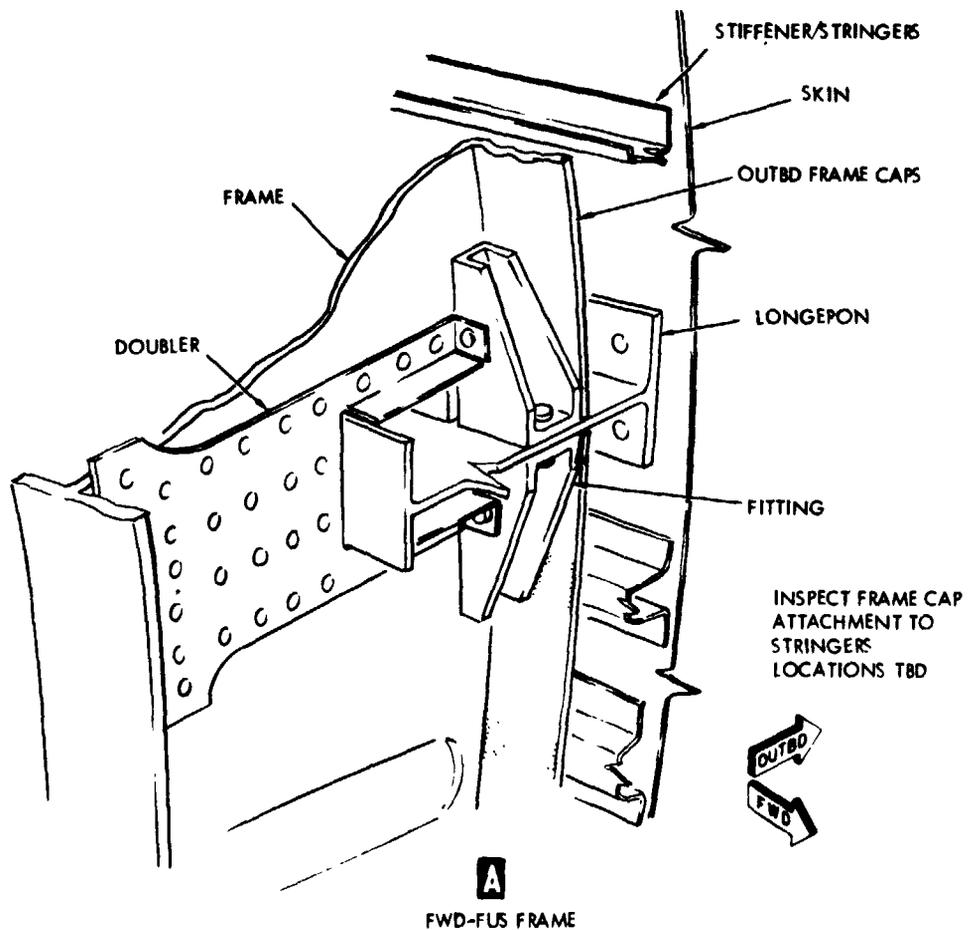
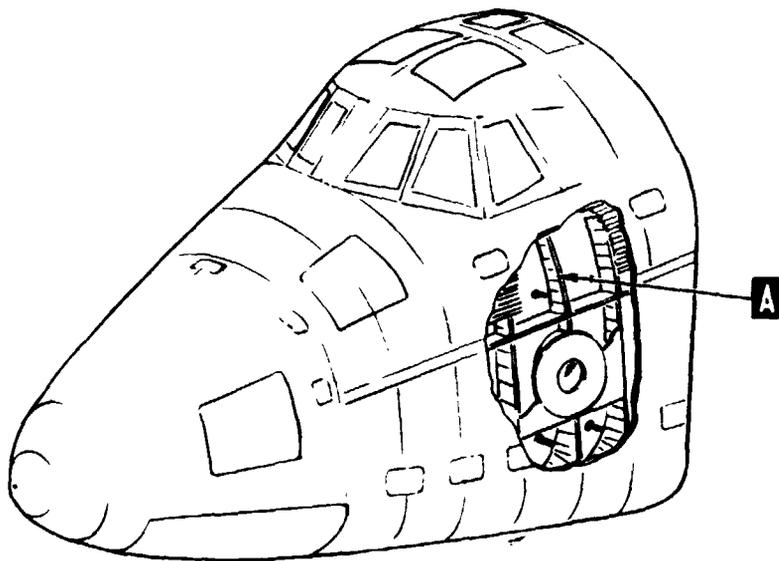


Figure 2-2. Forward Fuselage Frame Caps

PROCEDURE NO. 2-103, Figure 2-3

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 1 & 2 (X) POSTFLIGHT

SUBASSEMBLY: FWD FUSELAGE SHELL

DRAWING(S): VL70-001042

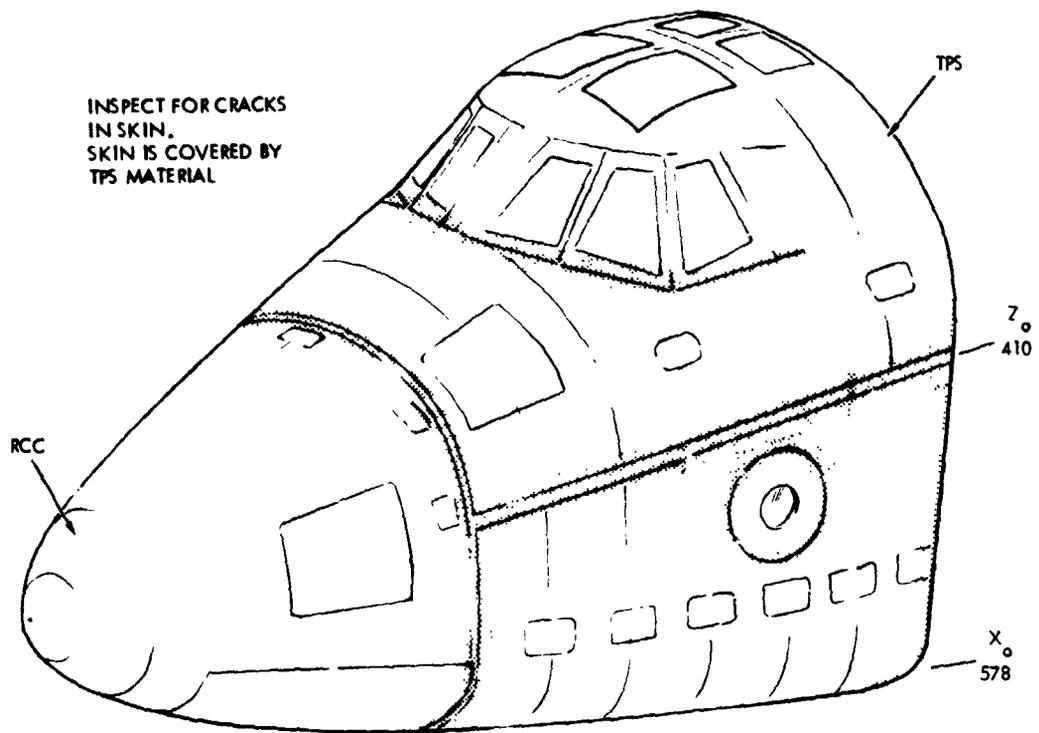
COMPONENT/AREA DESCRIPTION: FORWARD FUSELAGE SKINS: The skins on the forward fuselage are made from 2024-T86 formed sheet. The skins have a zinc chromate primer on both sides and finished with Supercoropon 515-700 (2 coats outside surface). They are stiffened by riveted-on hat-section stiffeners. Landing and flight loads may cause damage in the area of skin splices and cutouts.

DEFECTS: Through-cracks originating at rivets or edges near skin splice joints and around cutouts such as the crew hatch and star tracker doors.

ACCESS: Not directly accessible because of bonded TPS materials. Access for film placement or optical examination is reasonable in most areas. Removal of TPS in local suspect area will be necessary for backup NDI.

NDT TECHNIQUES: Primary: Radiographic or optical borescope (see paragraphs 1.5.6.2 or 1.5.1.3, respectively).

Backup: Eddy Current (see paragraph 1.5.4.4).



FWD FUS SHELL, SKIN PANEL SPLICES

Figure 2-3. Forward Fuselage Skins

PROCEDURE NO. 2-104, Figure 2-4

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, ZONE 1

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: WINDOW FRAMES

DRAWING(S): VL70-003258

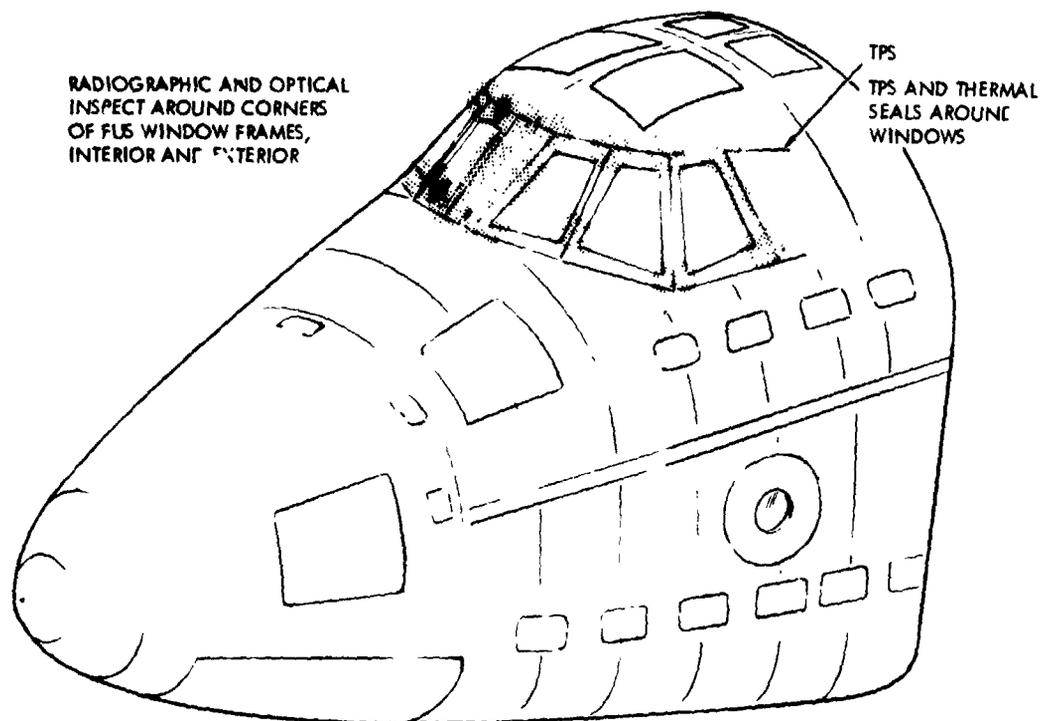
COMPONENT/AREA DESCRIPTION: WINDOW FRAMES, FUS SHELL: Six thermal windows are located forward of the flight station in the forward fuselage. The window frames are machined from a high temperature alloy and are riveted to structural panels and fuselage frames. The frames have a TBD finish. The windows and window frames receive loading from high-q boost, cabin pressurization, thermal stresses, and flight loads so that damage may result in fatigue in the window frame attachment areas.

DEFECTS: Cracks may develop in structure where window frames are attached around the fastener holes common to frame and structure and in the webs of attachment fittings.

ACCESS: Access is attained from inside the flight station (cockpit). Detailed access factors TBD.

NDT TECHNIQUES: Primary: Optical or X-ray (see paragraphs 1.5.1.3 or 1.5.6.2, respectively).

Backup: TBD



RADIOGRAPHIC AND OPTICAL
INSPECT AROUND CORNERS
OF FUS WINDOW FRAMES,
INTERIOR AND EXTERIOR

TPS
TPS AND THERMAL
SEALS AROUND
WINDOWS

 FWD FUS SHELL, WINDOW FRAMES

NOTE

IF FILM CAN BE PLACED BETWEEN FUSELAGE SHELL AND CREW CABIN,
AIM X-RAY TUBE FROM OUTSIDE OF SHELL

Figure 2-4. Window Frames, Fuselage Shell

PROCEDURE NO. 2-201, Figure 2-5

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR BOX

DRAWING(S): VL72-000027'B', VL70-001011,
VL70-326101

COMPONENT/AREA DESCRIPTION: NLG DRAG LINK SUPPORT FITTING:

Located at X_{\circ} 328, $X_{\circ} \pm 21.0$, and Z_{\circ} 329, this attachment area receives landing shock loads, landing roll and taxi loads from the NLG and transmits it to surrounding structure. Damage may initiate in the attachment area after repeated load cycles. The attachment fitting is made of 2024 aluminum alloy and finished with an abrasion-resistant polyurethane paint and is supported directly by the aluminum alloy NLG well ribs.

DEFECTS: Cracks may occur around the drag link attachment hole. Secondary cracking may possibly occur in the aluminum structure interfacing with the fitting.

ACCESS: The area is readily accessible from inside the NLG well with NLG fully extended.

NDT TECHNIQUES: Primary: Ultrasonic shear wave or eddy current (see paragraphs 1.5.5.3 B and C and 1.5.4.4, respectively).

Backup: Fluorescent penetrant (see paragraph 1.5.2.1

Figure 1-9).

PROCEDURE NO. 2-202, Figure 2-5

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR BOX

DRAWING(S): VL70-003258, VL70-000027B,
VL70-001011

COMPONENT/AREA DESCRIPTION: NOSE LANDING GEAR TRUNNION SUPPORT FITTING. Located in the NLG well just forward of the X_o 378 bulkhead at X_o 376, Z_o 298, and Y_o ±21. The NLG is supported via the trunnion fittings attached to two longitudinal beams which form the outboard confines of the NLG well. The trunnion fitting receives landing shock loads, rollout and taxi loads. The fitting is machined from 2124-T851 aluminum alloy plate and is finished with an abrasion-resistant polyurethane enamel system.

DEFECTS: Cracks may develop in the hole of the fitting or at the fillet where the lug blends into the base, particularly on the lower portion of the fitting.

ACCESS: The fitting is readily accessible from inside the Nose Landing Gear well with the NLG doors open.

NDT TECHNIQUE: Primary: Ultrasonic shear wave or eddy current (see paragraphs 1.5.5.3 B or C and 1.5.4.4, respectively).

Backup: Fluorescent penetrant (see paragraph 1.5.2.1, Figure 1-9).

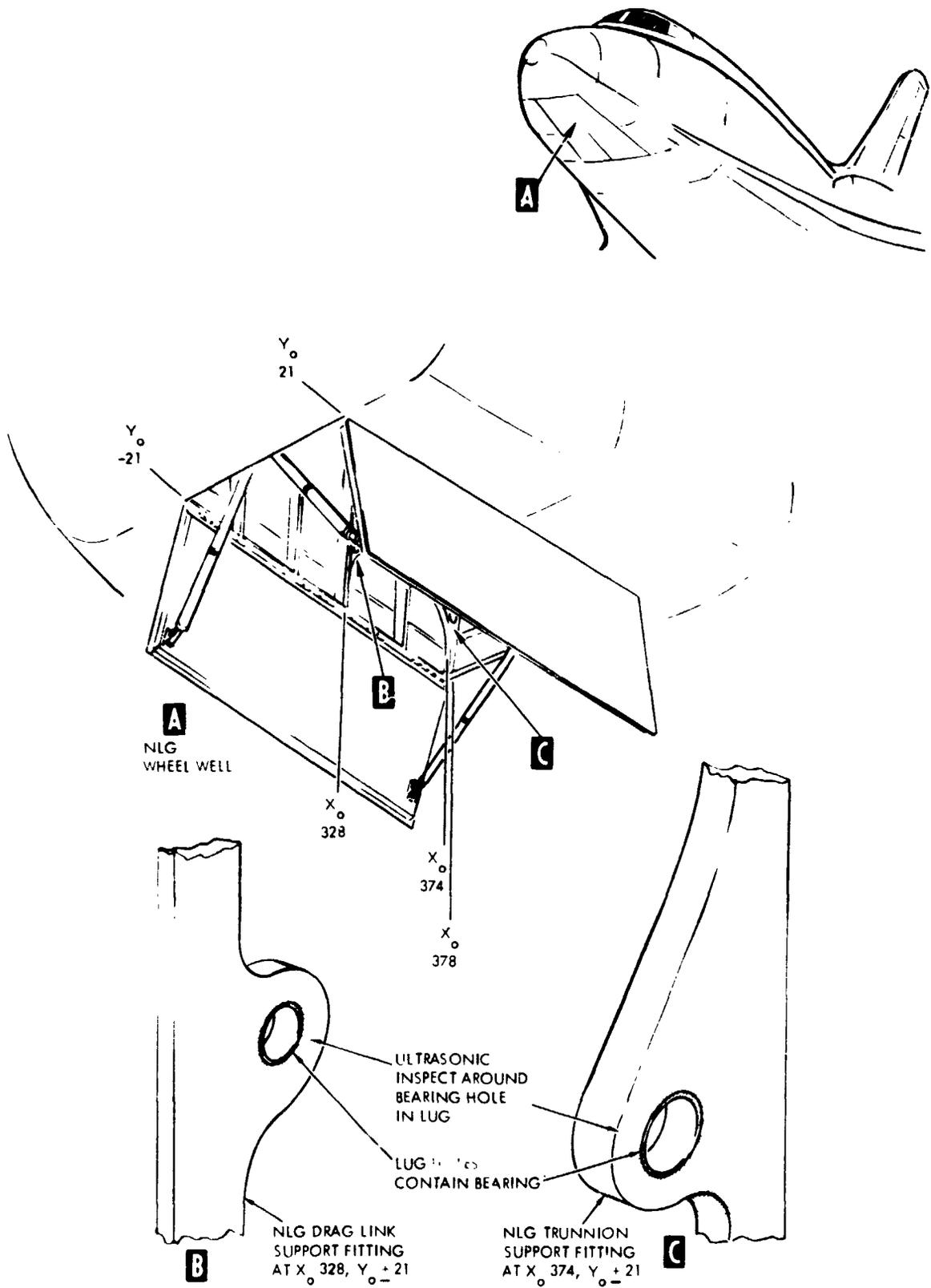


Figure 2-5. NLG Drag Link Support and Trunnion Support Fittings

PROCEDURE NO. 2-203, Figure 2-6

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG AXLE. The safe-life designed axle is a machined 300M steel forging. The axle is normally housed in the piston cross tube. It is subject to high bending and shear loads during the taxi turns and adverse landing conditions. Damage may occur to the splines and body of the axle.

DEFECTS: Cracked splines; circumferential cracks in the body of the axle.

ACCESS: Remove wheels from axle and axle from cross tube.

NDT TECHNIQUES: Primary: Magnetic particle, circular and longitudinal (see paragraph 1.5.3.2).

Backup: Fluorescent particle in spline areas (see paragraph 1.5.2.1, Figure 1-9).

PROCEDURE NO. 2-204, Figure 2-6

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE
ZONE 2

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S) VL72-000103A and 73MA5769
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG SHOCK STRUT PISTON: The shock strut piston is a 300M steel forging having an abrasion-resistant polyurethane enamel surface finish on the lower portions. The upper portion of the piston is normally housed in the shock strut main cylinder to transfer axial landing shock loads into the hydraulic/pneumatic chambers. The safe-life designed piston experiences high bending and shear loads during gear spin-up. The lower portion of the piston contains a cross tube to house the NLG axle and attachments for the torque link fittings.

DEFECTS: Circumferential cracks in the piston area and in the cross tube just outbd of the center section integral ribs; longitudinal stress-corrosion cracks in the forging parting plane; and radial cracks in the lower torque link attachment lugs.

ACCESS: NLG fully extended with piston maximum withdrawn from cylinder.

NDT TECHNIQUES: Primary: Magnetic particle for piston and cross tube (see paragraph 1.5.3.2 longitudinal) areas; ultrasonic shear wave for torque link lug (see paragraph 1.5.5.3B)

Backup: Magnetic particle for ultrasonic inspection verification (see paragraph 1.5.3.2).

PROCEDURE NO. 2-206, Figure 2-6

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5768
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG TORQUE LINKS: There are two upper and lower torque link arms on the NLG which are connected at a pivot joint and attached to the main cylinder and piston, respectively. They are made from 300M steel forgings and have an abrasion-resistant polyurethane enamel surface finish. The safe-life fittings experience high bending loads during gear spin-up. The pivot pin is also subjected to high shear loads.

DEFECTS: Radial cracks in the attachment lugs of both arms; circumferential cracks in the pivot pin.

ACCESS: NLG fully extended. Full access for inspection of lugs may be possible only by removing link arm assembly from the NLG, which is required for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave for lug areas (see para. 1.5.5.3 B) ultrasonic pulse-echo longitudinal wave (see para. 1.5.5.3A) for pivot pin in place or magnetic particle (see para. 1.5.3.2 circ.) for pivot pin removed.

Backup: Magnetic particle for ultrasonic inspection verification.

PROCEDURE NO. 2-207, Figure 2-6

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG LOWER DRAG BRACE. This safe-life fitting is made from 300M steel flash-welded tubing or forging and has an abrasion-resistant polyurethane enamel surface finish system. The fitting is the link between the upper drag brace and the NLG shock strut main cylinder. It is subjected to high tensile loads during gear spin-up and column compression loads during gear spring back.

DEFECTS: Radial cracks in the upper and lower pivot lugs. Cracks in the welds in flash-welded construction drag braces.

ACCESS: NLG fully extended. For backup inspection, lower drag brace may have to be disassembled from upper drag brace and NLG main cylinder.

NDT TECHNIQUES Primary: Ultrasonic shear wave for lug areas; (see para. 1.5.5.3 B) magnetic particle (see para. 1.5.3.2 circ.) for welded areas.

Backup: Magnetic particles (see para. 1.5.3.2 circ.)
for ultrasonic inspection verification.

PROCEDURE NO. 2-208, Figure 2-6

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S): VL72-000103A and 73MA 5769
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG UPPER DRAG BRACE. The upper drag brace is a 300M steel flash-welded tube or forging with an abrasion-resistant polyurethane enamel finish system. It is a wishbone-shaped fitting whose upper forks tie into the drag link trunnions in the NLG well ribs. The lower portion connects to the lower drag brace at a pivot joint. The safe-life fitting is subject to tension during gear spin-up and column compression during gear spring-back.

DEFECTS: Radial cracks in the upper and lower pivot lug. Cracks in the welds in flash-welded drag braces.

ACCESS: NLG fully extended. For backup inspection, the upper drag brace may have to be disassembled from NLG box structure.

NDT TECHNIQUES: Primary: Ultrasonic shear waves for lug areas (see para. 1.5.5.3 B); magnetic particle for welds (see para. 1.5.3.2 circ.)

Backup: Magnetic particles (see para. 1.5.3.2 circ.)
for ultrasonic inspection verification.

PROCEDURE NO. 2-209, Figure 2-6

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE,
ZONE 2

(X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG LOWER DOWN LOCK BRACE. The lower lock brace is a 7075-T6 or 300M aluminum forging with an abrasion-resistant polyurethane enamel surface finish. The fitting acts in concert with the upper lock brace to secure the NLG in the extended position during landing and ground operations. This safe-life fitting experiences high bending and shear loads during gear springback. This fitting may be subject to corrosion if the forging mounting plane is exposed for a sufficient time to a salt-laden atmosphere.

DEFECTS: Radial cracks in the four attachment/pivot lugs.

ACCESS: NLG fully extended. Lower down-lock brace may have to be removed from assembly for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (see para. 1.5.5.3 B).
Backup: Magnetic particle inspection (see para. 1.5.3.2 circ.)

PROCEDURE NO. 2-210, Figure 2-6

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG UPPER DOWN-LOCK BRACE.

The upper lock brace is a 300M steel forging which has an abrasion-resistant polyurethane enamel surface finish. This fitting is attached to the main shock strut cylinder upper end and acts in concert with the lower lock brace to secure the NLG in the extended position during landing and ground operations.

During landing and rollout the safe-life part experiences high bending and shear loads which could eventually result in damage to the part. One per orbiter.

DEFECTS: Radial cracks in the upper and lower attachment/pivot lug holes.

ACCESS: NLG fully extended. Down lock brace may have to be removed from landing gear assembly to perform backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (see para. 1.5.5.3 B).
Backup: Magnetic particle (see para. 1.5.3.2 circ).

PROCEDURE NO. 2-211, Figure 2-6

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, ZONE 2 TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: NOSE LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.2)

COMPONENT/AREA DESCRIPTION: NLG DRAG BRACE CROSS TIE: This fitting connects between the upper legs of the upper drag brace to react drag brace bending loads. It is made of 300M steel and has an abrasion-resistant polyurethane enamel surface finish. The safe-life fitting experiences high bending loads during gear spin-up. One per vehicle.

DEFECTS: Transverse cracks across the end caps; longitudinal cracks in the web-to-end cap transition.

ACCESS: NLG fully extended.

NDT TECHNIQUES: Primary: Magnetic particle for 300M steel fitting (see paragraph 1.5.3.2 circ).

Backup: None required.

☐ -- PROCEDURE NUMBER

M -- MAGNETIC PARTICLE INSPECTION

U-S -- ULTRASONIC SHEAR WAVE INSPECTION

U-L -- ULTRASONIC LONGITUDINAL WAVE INSPECTION

INSPECT: ALL LUG BOLT HOLES
LUG BASE INTERSECTIONS
PISTON AND CYLINDER PARTING PLANES
CROSS TUBE BODY INTERSECTIONS
WELDMENTS

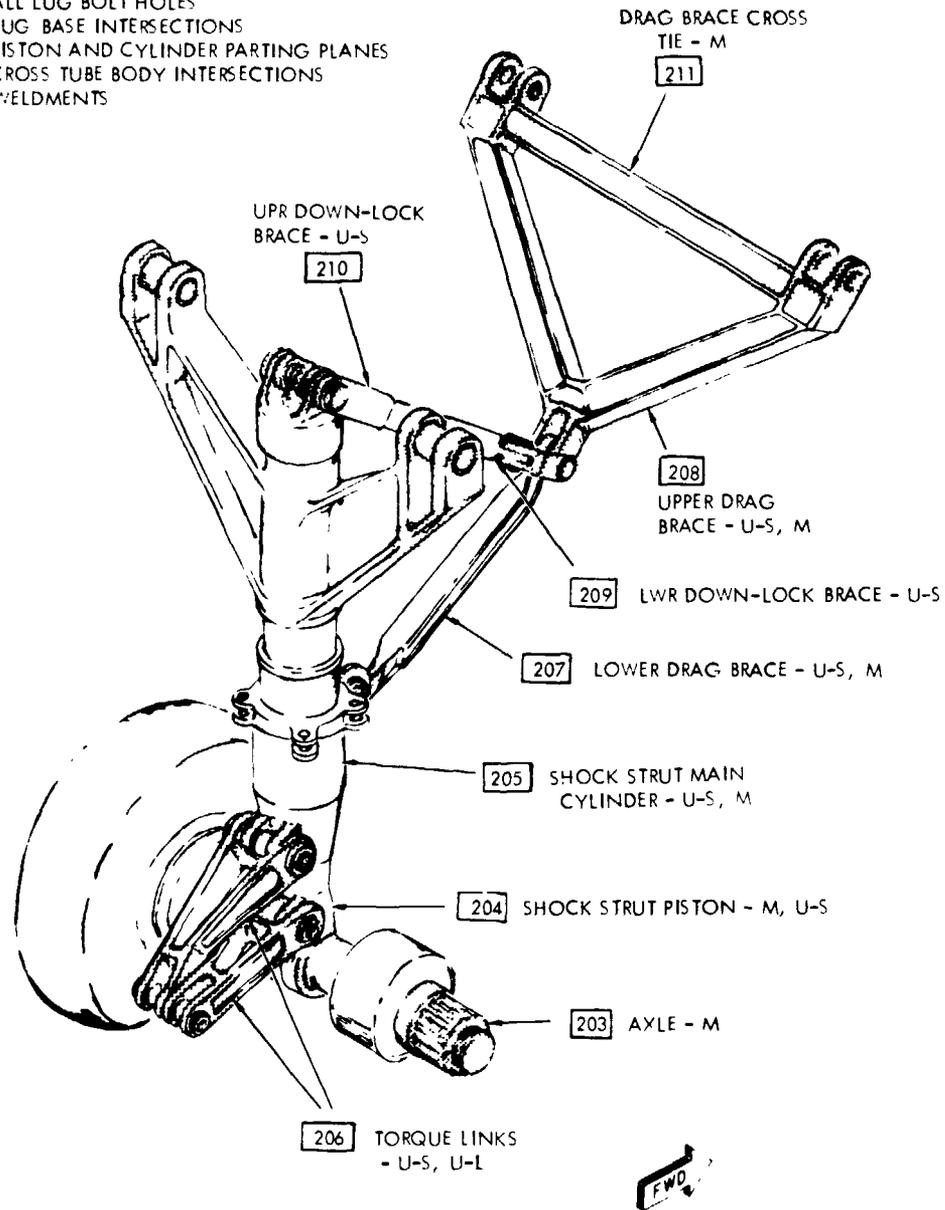


Figure 2-6. Nose Landing Gear Assembly

PROCEDURE NO. 2-212, Figure 2-7

		TYPE INSPECTION
<u>MAJOR ASSEMBLY:</u>	ORBITER, FORWARD FUSELAGE, ZONE 2	(X) POSTFLIGHT
<u>SUBASSEMBLY:</u>	ORBITER ET/ORB ATTACH	(X) PREFLIGHT
<u>DRAWING(S):</u>	VL72-000091	

COMPONENT/AREA DESCRIPTION: FWD ET/ORBITER ATTACH POINT: The attachment fitting is located at the base of the X₀ 378 bulkhead at Y₀ 0.0 on the bottom airframe surface just fwd of the crewcabin. It is made of (mat'l) and is finished with (finish system). This attachment provides the forward structure connection between the orbiter and the external tank. High interaction loads between the vehicles are reacted through this point, resulting from static and G-loads, vibro-acoustics, wind buffeting, aerodynamic loads that the Shuttle may experience prior to launch, at launch, and during ascent. In addition, sustained static loads combined with a salt spray atmosphere while the Shuttle is on the launch pad may result in stress-corrosion damage. The fitting should be inspected prior to launch and after landing.

DEFECTS: Cracks in the attachment lug of the fitting around the bolt-hole and in the fillet where the lug blends into the base of the fitting. Upper portions of the fitting are inside the fwd fuselage attached to the X₀ 378 bulkhead.

ACCESS: Access is readily attained by removing local TPS materials.

NDT TECHNIQUES: Primary: Ultrasonic (see para 1.5.5.3 B), fluorescent penetrant (see para. 1.5.2.1 Figure 1-9).

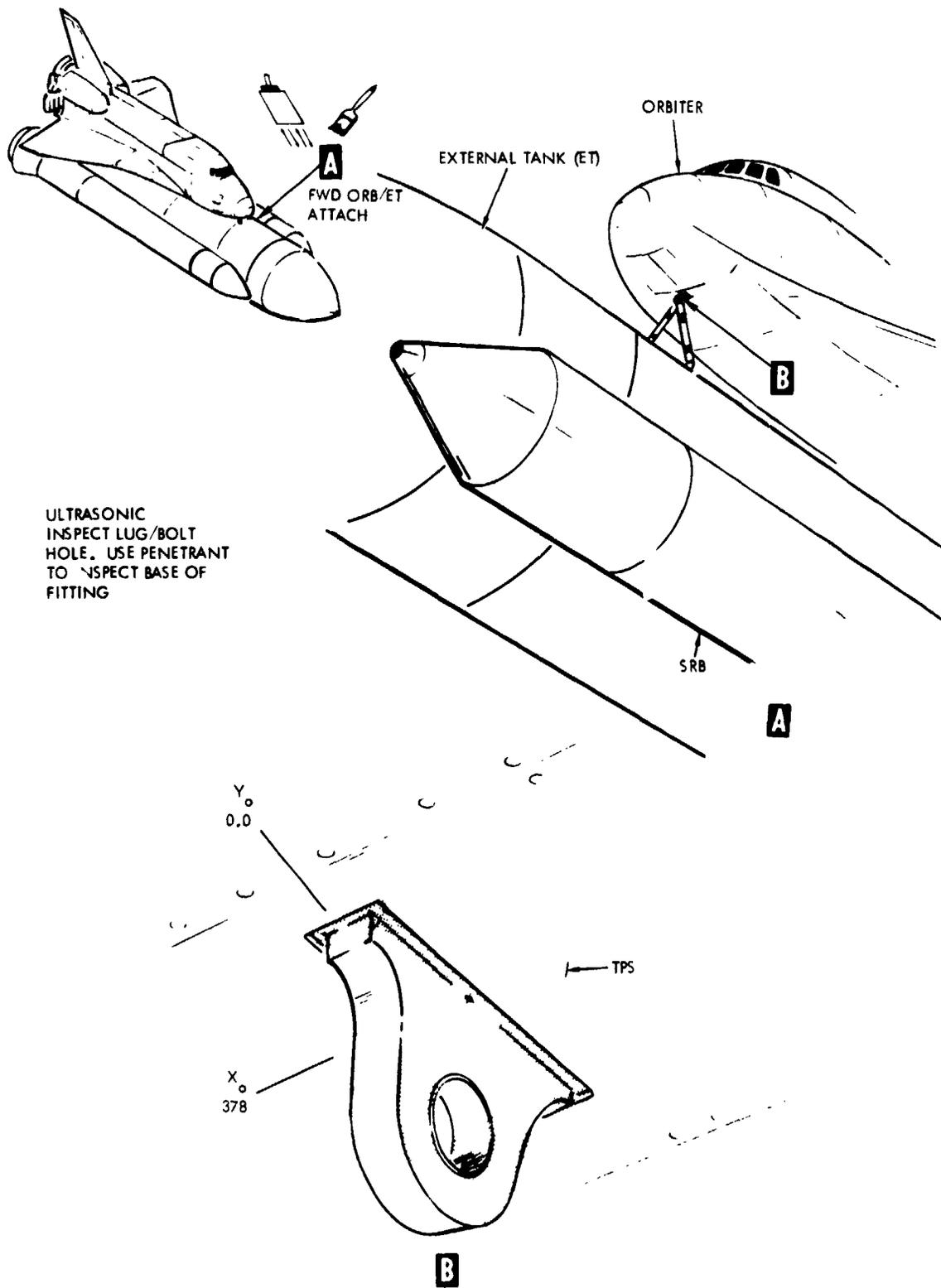


Figure 2-7. Forward ET/Orbiter Attach Fitting

PROCEDURE NO. 2-213, Figure 2-8

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 2 (X) POSTFLIGHT

SUBASSEMBLY: NOSE SECTION/RCS MODULE

DRAWING(S): VL70-001001 (PRR)

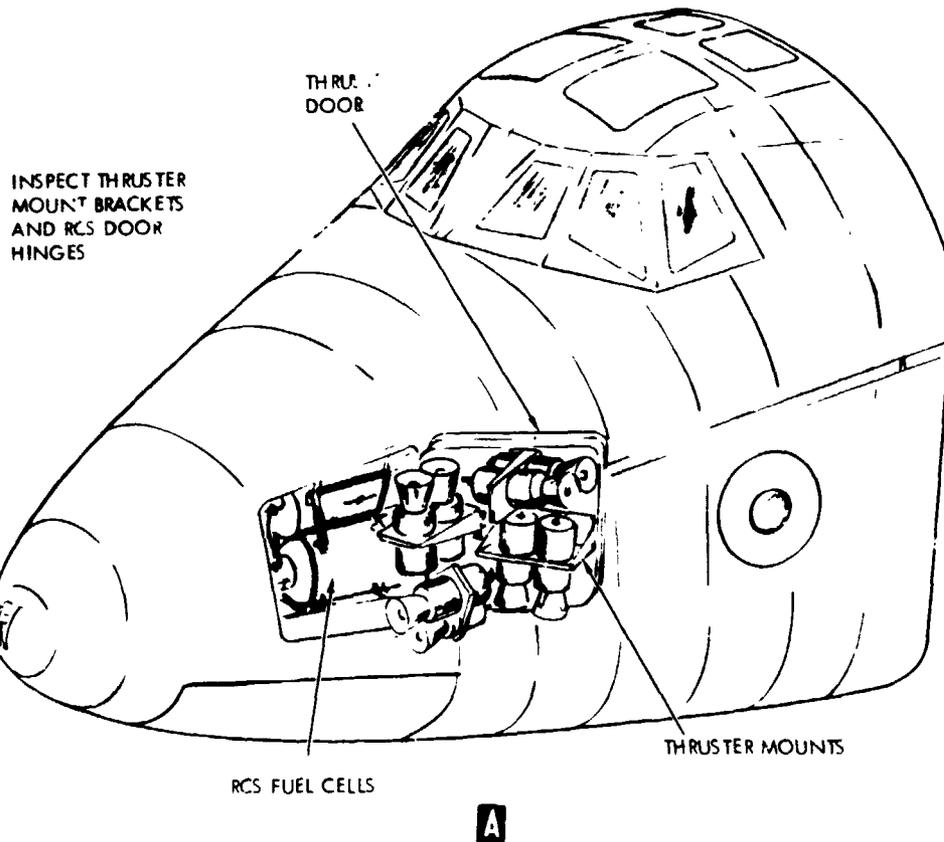
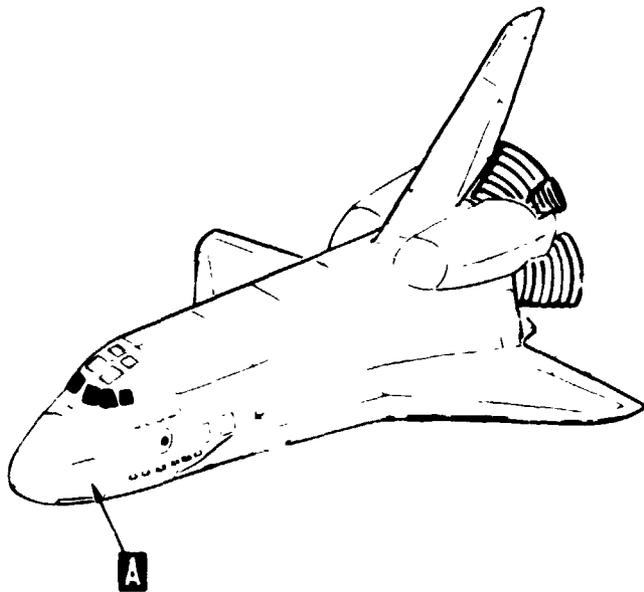
COMPONENT/AREA DESCRIPTION: FORWARD RCS MODULE STRUCTURAL ATTACHMENT AREAS:

The forward reaction control system (RCS) consists of propellant tanks, thrusters and firing and deployment controls located in the forward fuselage nose section, just above the NLG well, both sides of Orbiter. The RCS is used in on-orbit operations such as rendezvous, docking, undocking, attitude control and other orbital maneuvers, and in de-orbit operations to attain and maintain the correct de-orbit/re-entry attitude for the Orbiter vehicle. The thruster mounts and thruster module support structure is thus subjected to firing shock loads and short duration static loads. Eight thrusters are attached to each of two thruster deployment doors (other RCS thrusters are located on the OMS pods on the aft fuselage). The thrusters are mounted on the doors by the use of TBD (material/part) which have a zinc chromate primer/Supercorapon paint finish. The thrust is transmitted to the Orbiter through the deployment door hinges.

DEFECTS: Cracks in attachment holes of thruster mount fittings and at the base of these fittings. Also, cracks may develop in the hinge/attachment area where the deployment doors attach to the airframe structure.

ACCESS: Open RCS thruster deployment doors on each side of forward fuselage nose section.

NDT TECHNIQUES: Primary: Eddy current (see paragraph 1.5.4.4)
Backup: Fluorescent penetrant (see paragraph 1.5.2.1
Fig. 1-9).



INSPECT THRUSTER
MOUNT BRACKETS
AND RCS DOOR
HINGES

THRU.
DOOR

RCS FUEL CELLS

THRUSTER MOUNTS

A

FWD REACTION CONTROL SYSTEM THRUSTERS
L.H. SHOWN, R.H. OPPOSITE

Figure 2-8. Forward RCS Module Structural Attachment Areas

PROCEDURE NO. 2-214, Figure 2-9

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONES 2 & 3 (X) POSTFLIGHT

SUBASSEMBLY: CREW INGRESS/EGRESS HATCH

DRAWING(S): VL70-003258, VL70-003052

COMPONENT/AREA DESCRIPTION: CREW MODULE ENTRANCE HATCH OPENING. The hatch is centered at $X_o = 509$ and $Z_o = 368$, located on the left side of the forward fuselage only. The outer door is hinged in the forward fuselage shell on the lower aft side of the door opening and opens outwardly. The hatch is a circular penetration of 40 inches diameter into pressurized load bearing structure. Thus the cabin welded sill structure around the hatch opening and the outer door hinge area are subject to fatigue damage. The material of construction is 2024 aluminum alloy having a chromate primer and Supercorapon 515-700 paint finish.

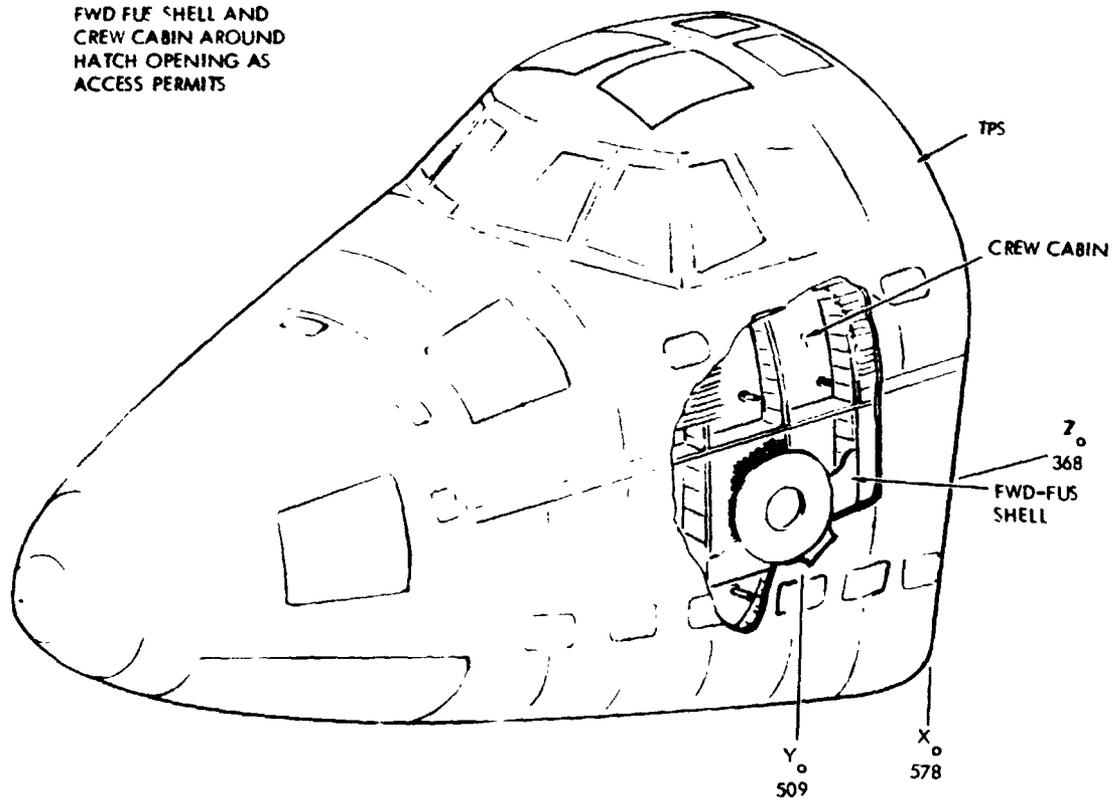
DEFECTS: Cracks forming in the hatch/cabin weldment and the sill frame structure. The hatch hinge and support structure in the fwd fus shell may also develop cracks.

ACCESS: Access is attained with the crew hatch open and with local internal insulation panels and/or bulkhead coverings removed.

NDT TECHNIQUES: Primary: Eddy current, (see para. 1.5.4.4) ultrasonic shear wave (see para. 1.5.5.3 C).

Backup: Fluorescent penetrant (see para. 1.5.2.1, Fig. 1-9).

INSPECT HINGE, FRAME,
AND SKIN STRUCTURE IN
FWD FUS SHELL AND
CREW CABIN AROUND
HATCH OPENING AS
ACCESS PERMITS



FWD FUS CREW CABIN -
CREW INGRESS EGRESS HATCH

Figure 2-9. Crew Module Entrance Hatch

PROCEDURE NO. 2-301, Figure 2-10

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 3 (X) POSTFLIGHT

SUBASSEMBLY: CREW CABIN

DRAWING(S): VL70-003052; VL70-001042A

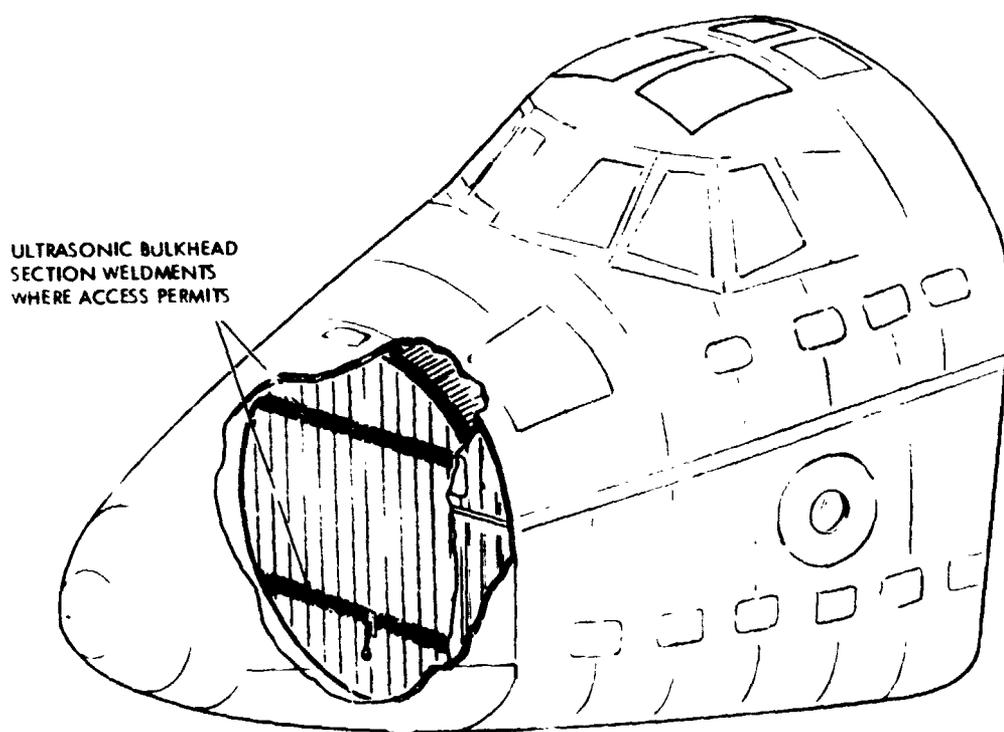
COMPONENT/AREA DESCRIPTION: CABIN FWD BULKHEAD. The forward bulkhead at $X_{\circ} 378$ is machined from 2219-T87 aluminum plate in a waffle grid design, built-up in fusion-welded sections. The entire cabin is a welded pressure vessel reinforced with internal ring frame and external longitudinal stringers. The forward bulkhead, as is true of the entire cabin, is subject only to internal pressure loadings. The bulkhead has both safe-life and fail-safe design features. A link attachment at $Y_{\circ} 0.0$, $X_{\circ} 378$ and $Z_{\circ} 292$ reacts Z-axis loads with respect to the fwd fuselage shell.

DEFECTS: Surface cracks along welds in bulkhead.

ACCESS: From inside the lower fwd fus (need to remove avionics or other equipment not determined. Access from nose section not determined).

NDT TECHNIQUES: Primary: Ultrasonic shear and/or surface wave (see para. 1.5.5.3 C or 1.5.5.1) or fluorescent penetrant (see para. 1.5.2.1 Fig. 1-9).

Backup: Eddy current (see para. 1.5.4.4) or fluorescent penetrant (see para. 1.5.2.1, Fig. 1-9)



CREW CABIN FORWARD BULKHEAD AT X 384

Figure 2-10. Cabin Forward Bulkhead

PROCEDURE NO. 2-302, Figure 2-11

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 3 (X) POSTFLIGHT

SUB ASSEMBLY: CREW CABIN

DRAWING(S): VL70-003240A, VL70-003258B

COMPONENT/AREA DESCRIPTION: CREW MODULE WINDOW FRAMES. The window frames in the crew module are composed of 2219-T6 aluminum alloy machinings welded into the module canopy. Since the windows are penetrations into primary pressurized structure, internal pressure loadings can cause stresses that may lead to fatigue damage in the weldments, particularly near the corners of individual windows and between windows. Initial weldment flaws may nucleate such damage.

DEFECTS: Cracks in or near weldments surrounding crew module window openings.

ACCESS: Access to the frames is attained from inside the flight station (cockpit) and by entering the flight deck forward access opening at X_o 450 and Y_o 0.0. Additional access for radiographic equipment is attained from outside the fuselage above the nose section. Internal wall coverings and some equipment removal may be necessary.

NDT TECHNIQUES: Primary: X-ray Radiography (see para. 1.5.6.2) and ultrasonic shear wave (see para 1.5.5.3 C)

Backup: Penetrant (see para. 1.5.2.1, Fig. 1-9)

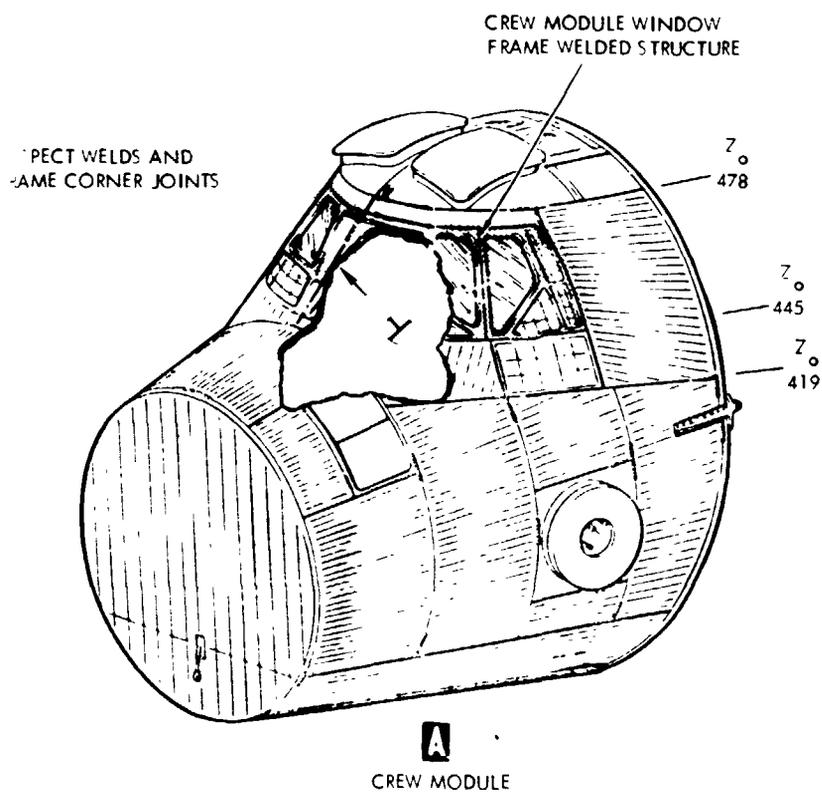
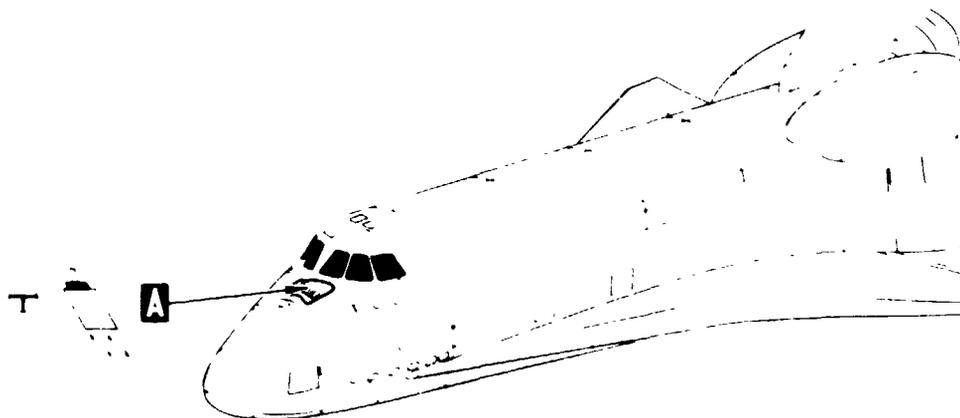


Figure 2-11. Crew Cabin Window Frames

PROCEDURE NO. 2-303, Figure 2-12

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 3 (X) POSTFLIGHT

SUBASSEMBLY: CREW CABIN

DRAWING(S) VL70-003052

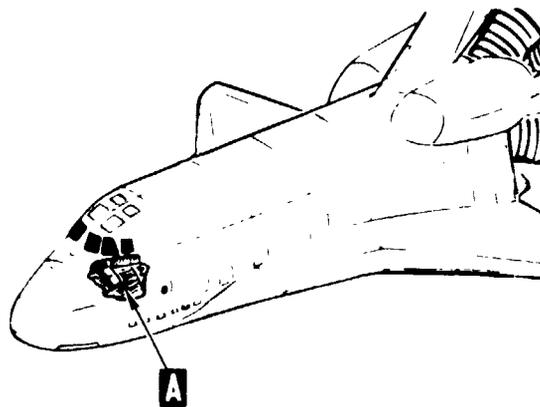
COMPONENT/AREA DESCRIPTION: CABIN CANOPY PANELS (ABOVE Z₀ 419).

Panels that surround the crew cabin window openings including the "eyebrow" panel are made of 2219-T87 aluminum formed sheets and are welded together. They are of fail-safe and safe-life design to withstand internal pressure tensile loadings. Except for the "eyebrow" panel, the panels are located between flight deck floor (Z₀ 419) and the upper window sill (Z₀ 478); the "eyebrow" panel is just above the upper sill, just forward of the X₀ 405 fus sta. The cabin interior has a low-outgassing polyurethane paint finish and the cabin exterior has a zinc chromate primer and Supercoropon paint finish.

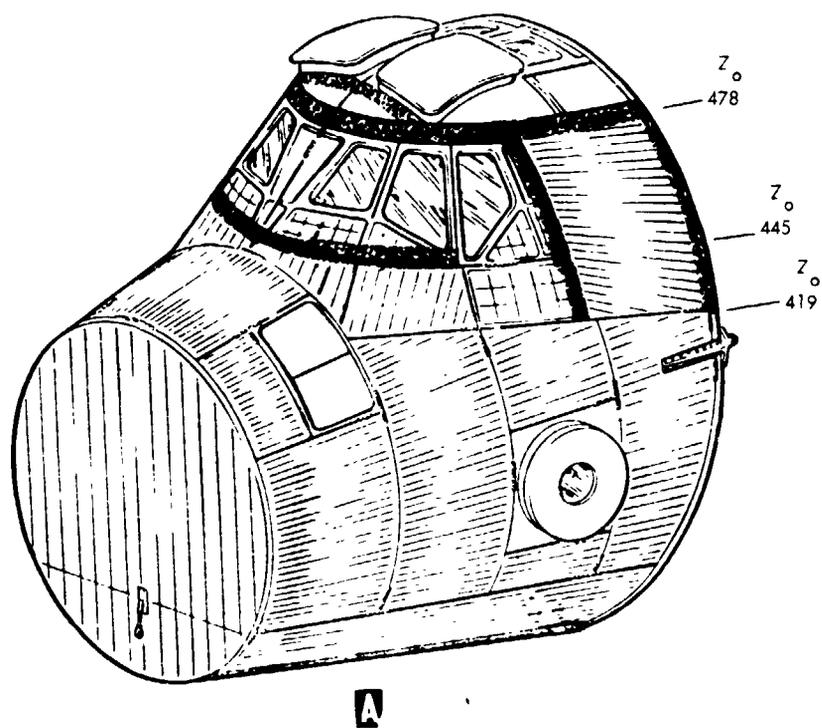
DEFECTS: Cracks in the fusion welds at panel joints and in the corners of the window cut-outs.

ACCESS: From inside the crew cabin flight station including the portion fwd of the cockpit. Bulkhead coverings and internal access panels must be removed.

NDT TECHNIQUES: Primary: Ultrasonic shear and/or surface wave (see para. 1.5.5.3 C or 1.5.5.1) or x-ray radiography (see para. 1.5.6.2) for welds.
Backup: Fluorescent penetrant (see para. 1.5.2.1, Fig 1).



ULTRASONIC OR
 RADIOGRAPHIC (DEPENDENT ON
 INSPECT WELDS ACCESS)
 AROUND CANOPY
 JOINTS



CREW CABIN CANOPY PANELS

Figure 2-12. Cabin Canopy Panels

PROCEDURE NO. 2-304, Figure 2-13

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, ZONE 3

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: CREW CABIN

DRAWING(S): VL70-003240 'A'

COMPONENT/AREA DESCRIPTION: CABIN MFG ACCESS PANEL. This panel is located atop the crew module aft of the window frames and contains the upper crew hatch. The panel is machined from 2219-T6 aluminum alloy plate and has a Supercorapon 515-700 finish. The panel is welded into the surrounding skin panel. The welded area should be inspected including the corners of the outer panel and the corners of the crew hatch in the mfg access panel. Loading on the panel is tensile burst stresses produced by internal pressurization. The mfg panel is defined by boundaries $Y_o \pm 37$ and $X_o 485$ to $X_o 560$.

DEFECTS: Cracks in weldments (seeded by initial weld defects); at corners of the surrounding skin panel (exterior to mfg. panel); and at corners of crew hatch in the mfg access panel.

ACCESS: From inside upper crew cabin and from outside top of forward fuselage. For backup, removals of hatch door, interior insulation and equipment may be necessary.

NDT TECHNIQUES: Primary: X-ray radiography (see para. 1.5.6.2).
Backup: Eddy current and/or shear wave, depending on area access (see para. 1.5.4.4 or para. 1.5.5.3 C)

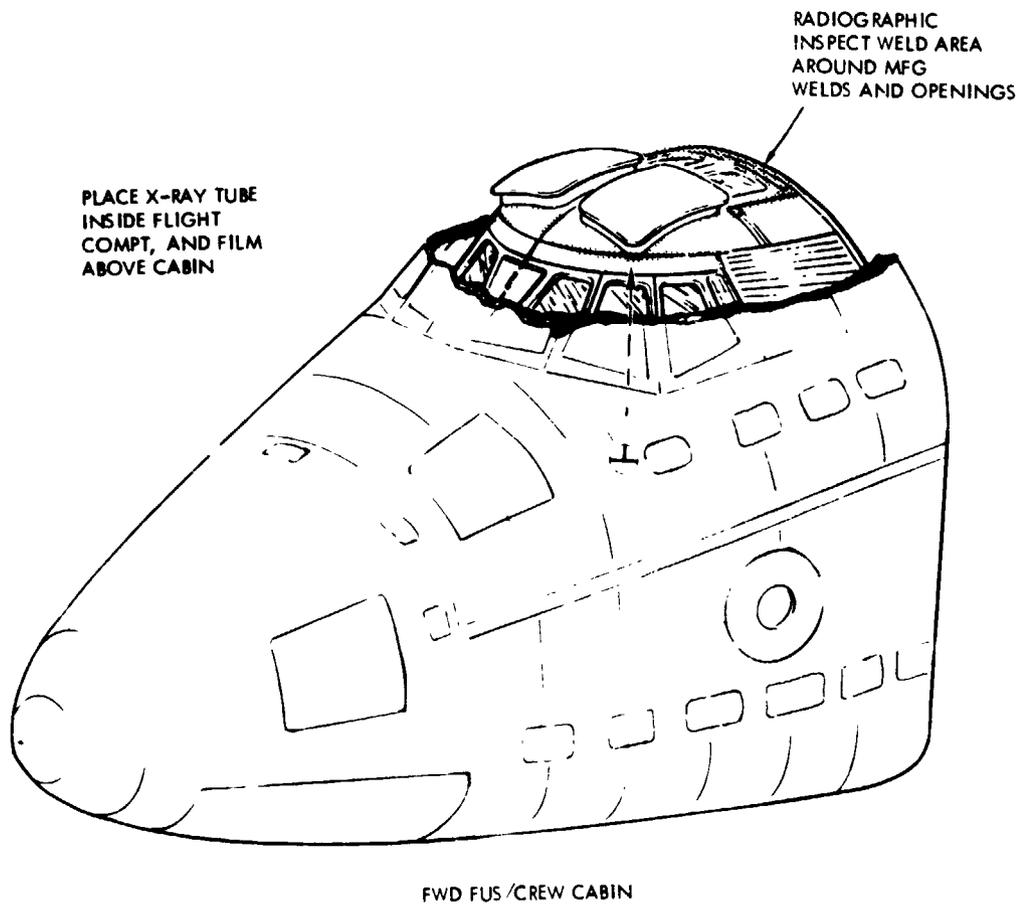


Figure 2-13. Cabin Manufacturing Access Panels

PROCEDURE NO. 2-305, Figure 2-14

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 3 (X) POSTFLIGHT

SUBASSEMBLY: CREW CABIN

DRAWING(S): VL70-003052

COMPONENT/AREA DESCRIPTION: CABIN FLOOR-BULKHEAD BEAMS. These beams of 2129-T87 aluminum machined plate are situated along both the flight compartment floor line and the crew/passenger compartment floor line, circumferentially around the cabin. They carry only internal pressure tensile loading and equipment weights. The beams should be inspected in the vicinity of attachments to the internal ring frames and at the fwd and aft bulkhead/sidewall intersections. The frame or bulkhead locations are X_o 376, 410, 442, 476, 502, 542, and 576 at Z_o 419 and Z_o 328, both sides of cabin.

DEFECTS: Vertical cracks in the fastener attach holes in the vertical members of the beam; longitudinal cracks in the fastener attach holes in the horizontal member(s).

ACCESS: From inside the cabin, upper and lower compartments. Will require equipment and TCS removal (TBD) and possible floor panel removals (TBD).

NDT TECHNIQUES: Applicable Methods: Eddy current surface probe (see para. 1.5.4.4) ultrasonic shear wave (see para. 1.5.5.3 C) and radiography (para. 1.5.6.2)

NOTE: Better definition of beam structure design and access are needed for assignment of NDT technique.

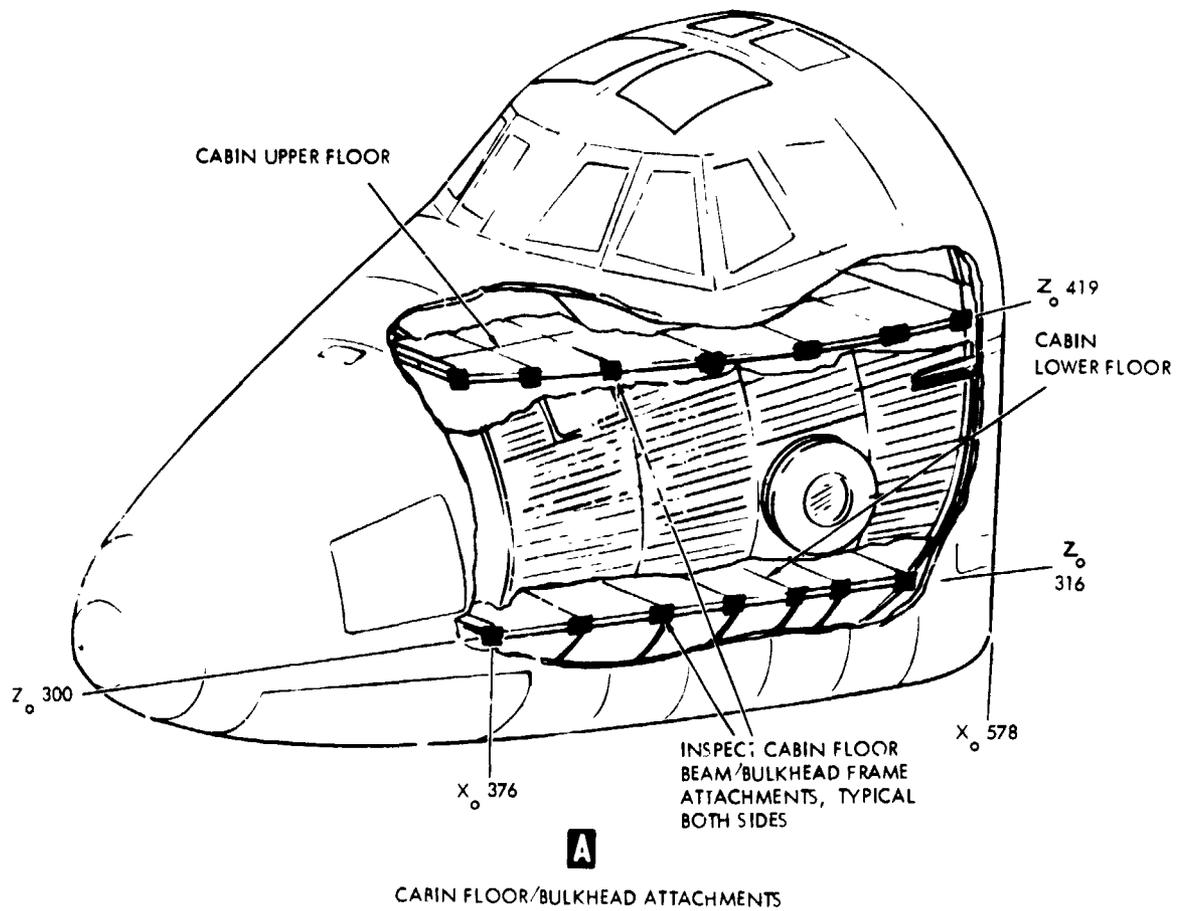
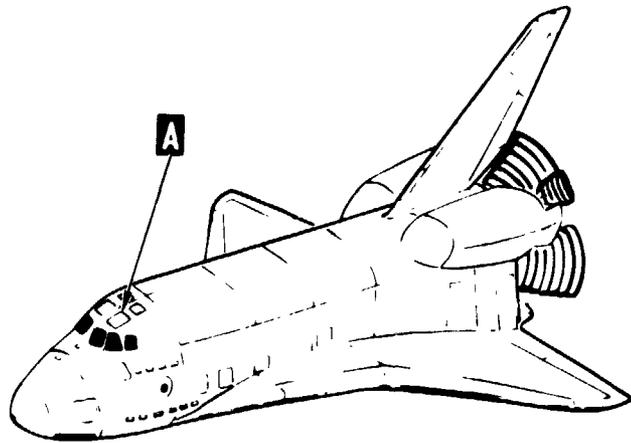


Figure 2-14. Cabin Floor/Bulkhead Beams

PROCEDURE NO. 2-306, Figure 2-15

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 3 (X) POSTFLIGHT

SUBASSEMBLY: CREW CABIN

DRAWING(S): VL70-003052

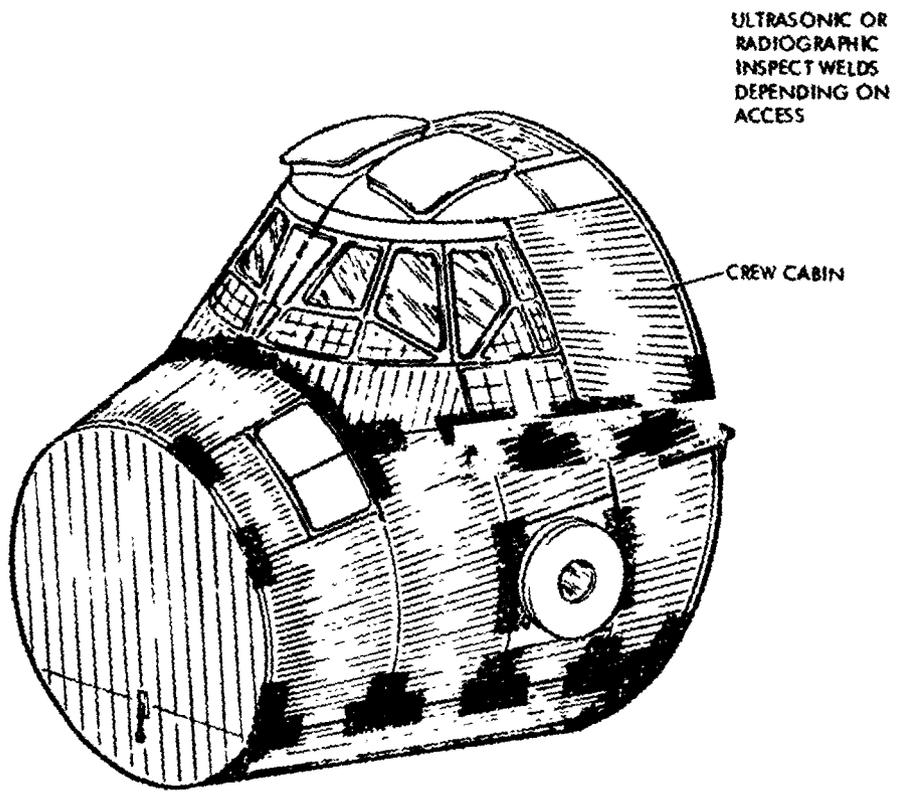
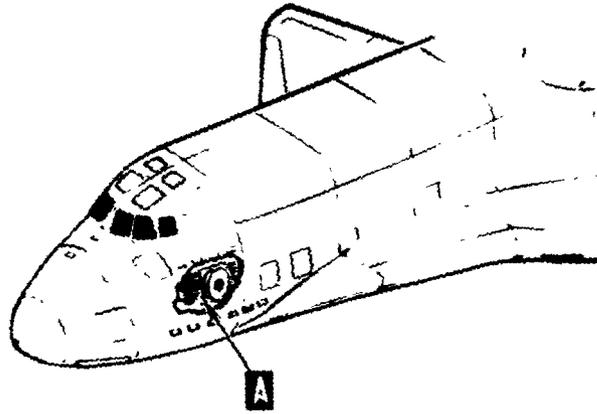
COMPONENT/AREA DESCRIPTION: CABIN SKIN PANELS (BELOW Z_o 419):

The cabin skin panels are machined from 2219-T87 aluminum plate, formed to shape and given 2219 aluminum stiffeners on the internal side. The skin panels are fusion welded together and have both fail-safe and safe-life design features. The cabin internal finish consists of low-outgassing polyurethane paint. The skins are subjected to internal pressure tensile loads and may eventually develop through-cracks that result in leaks. The skin should be given a general inspection around fastener holes at frame and floor beam attachment areas and at the corners of cabin penetrations.

DEFECTS: Cracks along the fusion welds at floor beam attachments, window sills, hatch manufacturing access panels and at fwd and aft bulkheads.

ACCESS: From inside the cabin upper and lower compartments. Removal of equipment and TCS materials will be required (not defined).

NDT TECHNIQUES: Primary: Ultrasonic shear and/or surface wave (see para. 1.5.5.3 C or 1.5.5.1) for welds where access permits. Optical, eddy current and x-ray may be applied to other areas where access requirements dictate.



A
CREW CABIN SKIN
PANEL WELDMENTS

Figure 2-15. Cabin Skin Panels

PROCEDURE NO. 2-307, Figure 2-16

MAJOR ASSEMBLY: ORBITER, FORWARD FUSELAGE, TYPE INSPECTION
ZONE 3 (X) POSTFLIGHT

SUBASSEMBLY: CREW CABIN

DRAWING(S): VL70-003052

COMPONENT/AREA DESCRIPTION: CABIN AFT BULKHEAD: The cabin aft bulkhead at X_o 576 is a machined 2219-T87 aluminum plate waffled-design structure which is combined in three fusion-welded sections. The aft bulkhead is subject to internal pressure tensile stresses and to cabin support loadings at four attach points where it is cantilevered from the X_o 578 bulkhead. The aft bulkhead has both safe-life and fail-safe design features. (Finish system TBD). The cabin is supported from the aft closure bulkhead at Z_o 400 where trunnion fittings react vertical and longitudinal loads and another link at Z_o 281, Y_o 0, which reacts transverse loads only.

DEFECTS: Surface cracks in the welds in bulkhead, and cracks in vicinity of cabin/bulkhead attach points.

ACCESS: From inside crew cabin - upper and lower compartments. (Equipment, TCS and panels will have to be removed -- TBD).

NDT TECHNIQUES: Primary: Ultrasonic shear and/or surface waves (see para. 1.5.5.3 C or 1.5.5.1) for welds. Ultrasonic or eddy current for other areas.

Backup: TBD

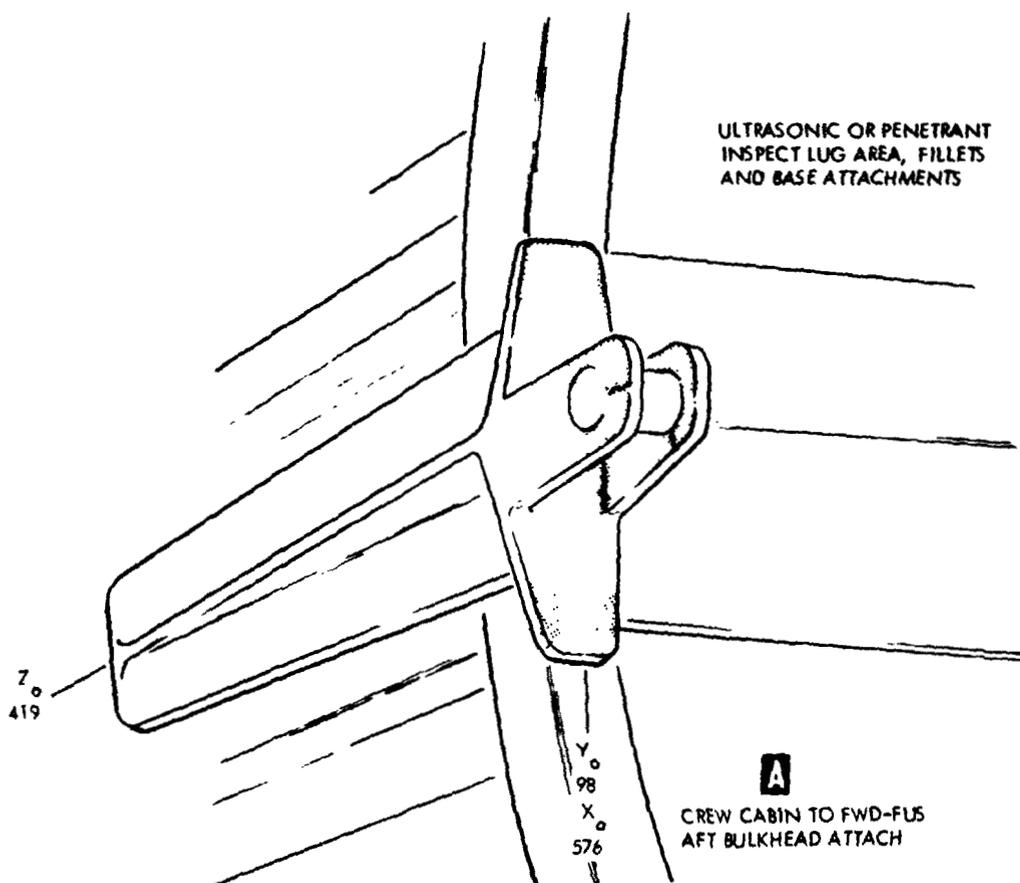
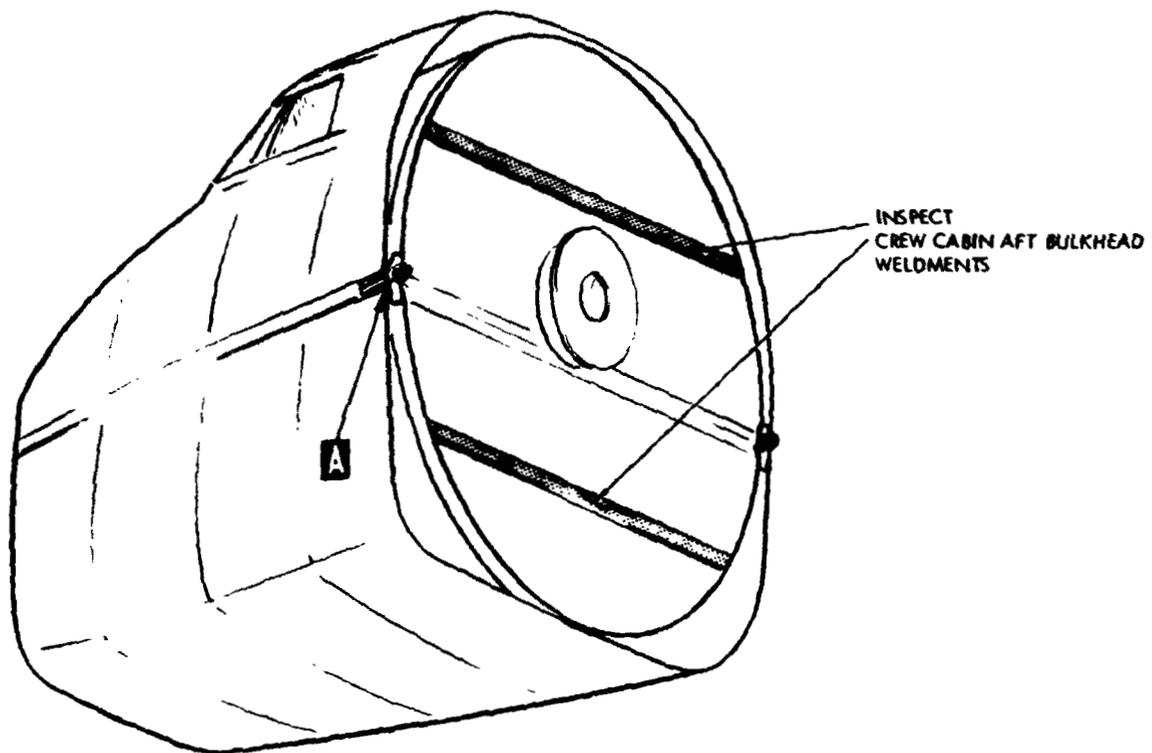


Figure 2-16. Cabin Aft Bulkhead

SECTION 3 - MID FUSELAGE STRUCTURE

This section contains the NDE requirements for the mid fuselage cargo bay structure, wing carry through box, payload bay doors and radiators, forward wing glove and wing interface.

SECTION 3
TABLE OF CONTENTS

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
3-401	Payload Bay Forward Sill Longeron	3-1
3-402	Payload Bay Lower Forward Longeron	3-3
3-403	Glove Fairing Skins	3-5
3-404	Mid-Fuselage Access Openings	3-7
3-405	Forward ECS Radiator Panel Hinges	3-9
3-406	Wheel Well Inner/Outer Access Openings	3-11
3-407	Lower Skin Panels	3-13
3-408	Payload Door Power Hinges	3-15
3-409	Payload Door Idler Hinges	3-16
3-410	Payload Sideload Retention Fittings	3-18
3-411	Side Skin Panels	3-20
3-412	Wing Carry-Through Skins	3-22
3-413	Wing Carry-Through Spar Frames	3-25
3-414	Wing-to-Fuselage Lower Aft Longeron Tension Tie	3-27
3-415	Mid-Fuselage Lower Aft Longeron	3-29
3-416	Payload Bay Aft Sill Longeron	3-32

SECTION 3
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
3-1	Payload Bay Forward Sill Longeron	3-2
3-2	Payload Bay Lower Forward Longeron	3-4
3-3	Glove Fairing Skins	3-6
3-4	Mid-Fuselage Access Openings	3-8
3-5	Forward ECS Radiator Panel Hinges	3-10
3-6	Frame Corners, Inner/Outer Access Opening	3-12
3-7	Mid-Fuselage Lower Skin Panels	3-14
3-8	Payload Bay Power and Idler Hinges	3-17
3-9	Payload Bay Sideload Retention Fittings	3-19
3-10	Mid-Fuselage Side Skin Panels	3-21
3-11	Mid-Fuselage Wing Carry-Through Skins	3-23
3-12	Wing Carry-Through Spar Frames	3-26
3-13	Wing/Fuselage Lower Aft Longeron Tension Tie	3- 8
3-14	Mid-Fuselage Lower Aft Longeron	3-30
3-15	Payload Bay Aft Sill Longeron	3-33

PROCEDURE NO. 3-401, Figure 3-1

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE, TYPE INSPECTION
ZONE 4 (X) POSTFLIGHT

SUBASSEMBLY: PAYLOAD BAY SILL LONGERON

DRAWING(S): CONVAIR MC621-0006-3.1.1.1-1;
VL70-000044

COMPONENT/AREA DESCRIPTION: PAYLOAD BAY FWD SILL LONGERON:

The 2024 aluminum alloy sill longeron attaches to the X₀ 576 fwd fus bulkhead at Z₀ 410 and Y₀ ±100. The part is made from an extrusion and has a zinc chromate primer and Supercorapon 515-700 paint finish. The sill longeron helps to support mid-fuselage purge pressure, torsional and bending loads and transfers flight and thrust loads to the fwd fuselage. Damage may occur in the attachment area to the fwd fuselage bulkhead and around mid-fus frame attachments from station X₀ 639 forward to the bulkhead.

DEFECTS: Cracks around fastener holes on longeron-fwd fus attachment pads (butt splice); cracks at attachments to mid fus frame.

ACCESS: Access is gained from inside the payload bay. Remove one bolt at a time in the longeron to fwd fus butt splice. Payload liner and thermal insulation may need to be removed at local areas.

NDT TECHNIQUES: Primary: Eddy current bolt hole at butt splice (see para. 1.5.4.3); ultrasonic and eddy current at frame attachment area (see para 1.5.5.3 C or para. 1.5.4.4).

Backup: Fluorescent penetrant (see para 1.5.2.1 Fig. 1-9).

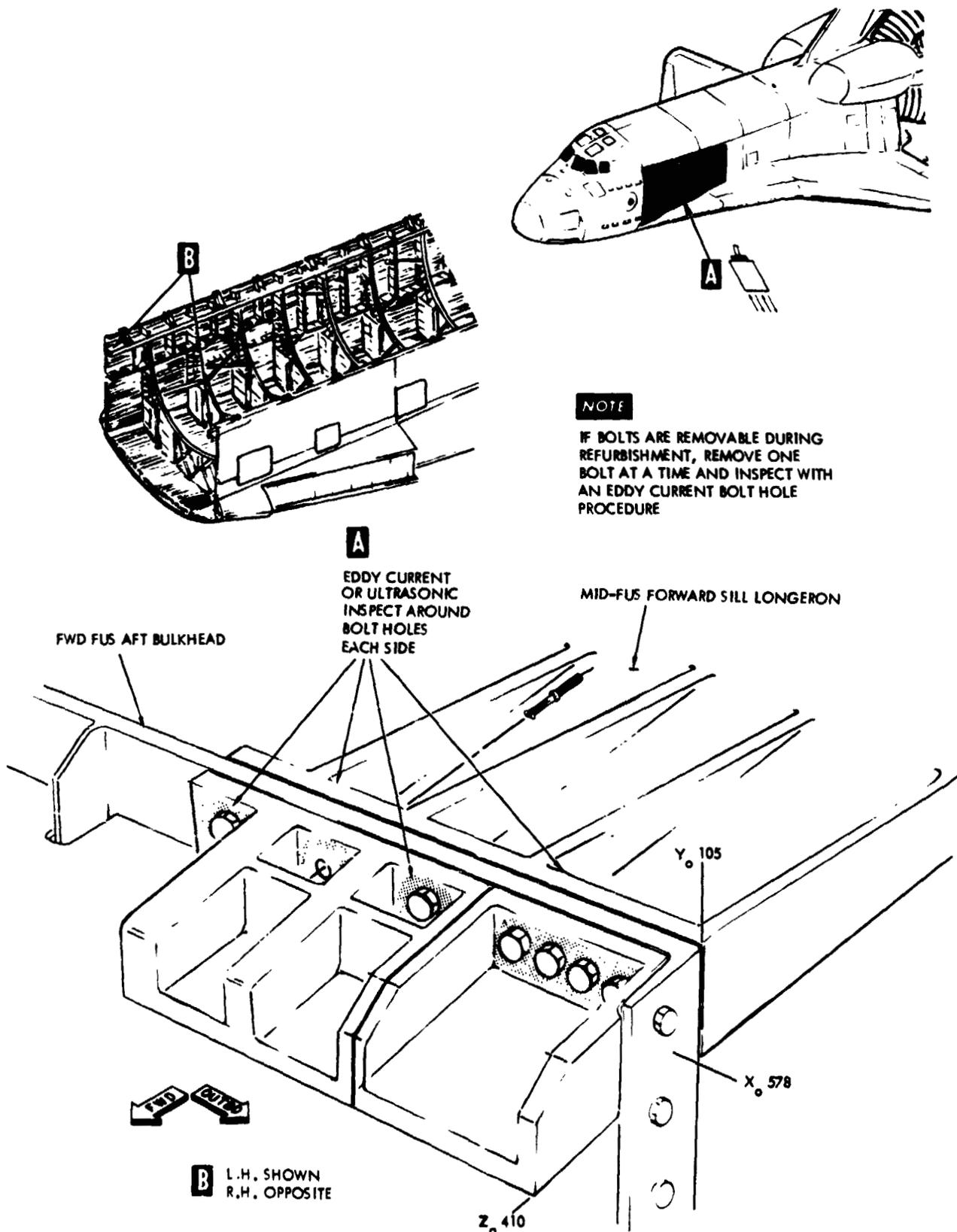


Figure 3-1. Payload Bay Forward Sill Longeron

PROCEDURE NO. 3-402, Figure 3-2

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: MID-FUS LOWER LONGERON

DRAWING(S):

COMPONENT/AREA DESCRIPTION: PAYLOAD BAY LOWER FORWARD

LONGERON: The lower mid-fus longeron is made of 2024 aluminum alloy extrusion and has a zinc-chromate primer and a Supercorapon 515-700 finish. The longeron is used as a mating element for the mid-fus lower and side skin panels and the wing glove skin. The longeron may be affected by fuselage torsion and bending, purge pressure and wing flexure loads. The portion of the longeron forward of X₆₃₆ and its attachment at the X₅₈₂ bulkhead should be inspected for flight damage. The outboard flange of the longeron should also be inspected in the vicinity of fuselage frames at X₆₉₃, X₇₅₀, X₈₀₇, X₈₆₃, and X₉₂₀.

DEFECTS: Longitudinal cracks where the outboard flange blends into the vertical flange at the fus frame stations; transverse cracks originating at fastener holes at the attachments to the X₆₀₉ frame and X₅₈₂ bulkhead.

ACCESS: The forward portion can be inspected at attachments from inside the mid-fuselage underfloor crawl-space by entering from the wheel well/fuselage access opening. The outboard flange is inspected by entering the wing glove box through the glove access openings.

NDT TECHNIQUES: Primary: Eddy current (para 1.5.4.4) and ultrasonic shear wave (para. 1.5.5.3 C).

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig 1-9) for cracks in flange. Eddy current bolt hole (para 1.5.4.3) for cracks at attach fasteners (fastener removed).

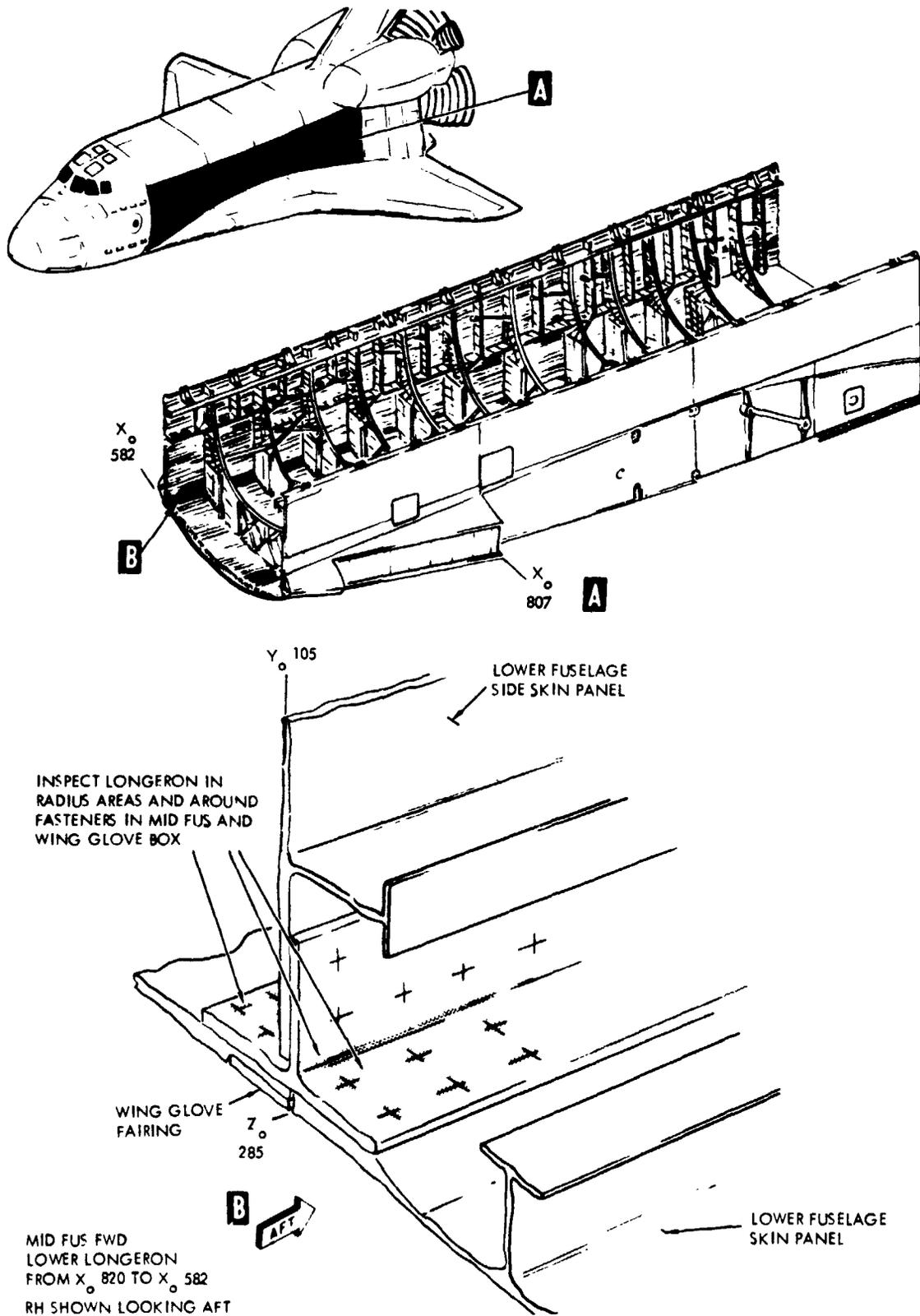


Figure 3-2. Payload Bay Lower Forward Longeron

PROCEDURE NO. 3-403, Figure 3-3

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: WING GLOVE

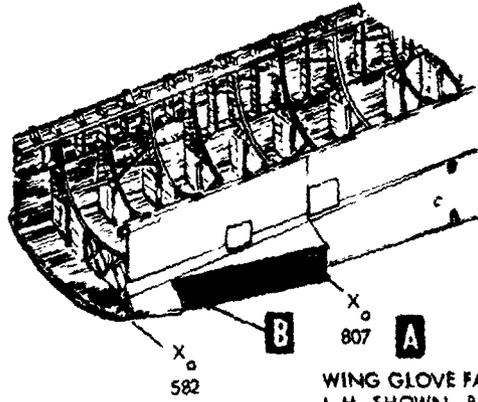
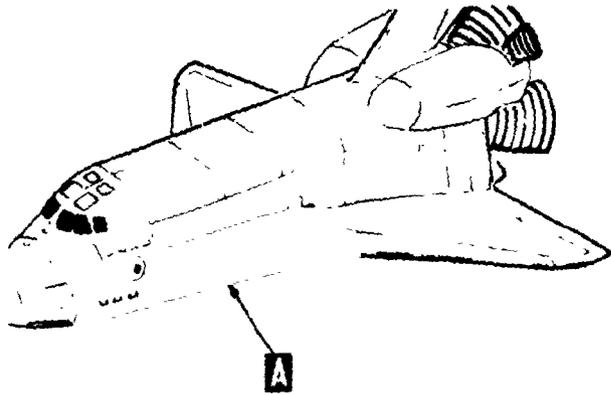
DRAWING(S): CONVAIR MC621-0006-3.1.1.1-1

COMPONENT/AREA DESCRIPTION: GLOVE FAIRING SKINS: The glove fairing skins are made of 2024-T81 aluminum alloy formed sheet which are given a zinc chromate primer and Supercorapon 515-700 finish and are protected on the exterior by HRSI/TPS. The skins are reinforced by internal stringers and spars and are attached to the mid-fuselage at X_o 807, extending fwd to X_o 582. Tensile stresses are induced in the skins during high-q boost, which may produce damage in certain locations.

DEFECTS: Skin cracks along leading edge and skin attachment fastener holes at leading edge spar.

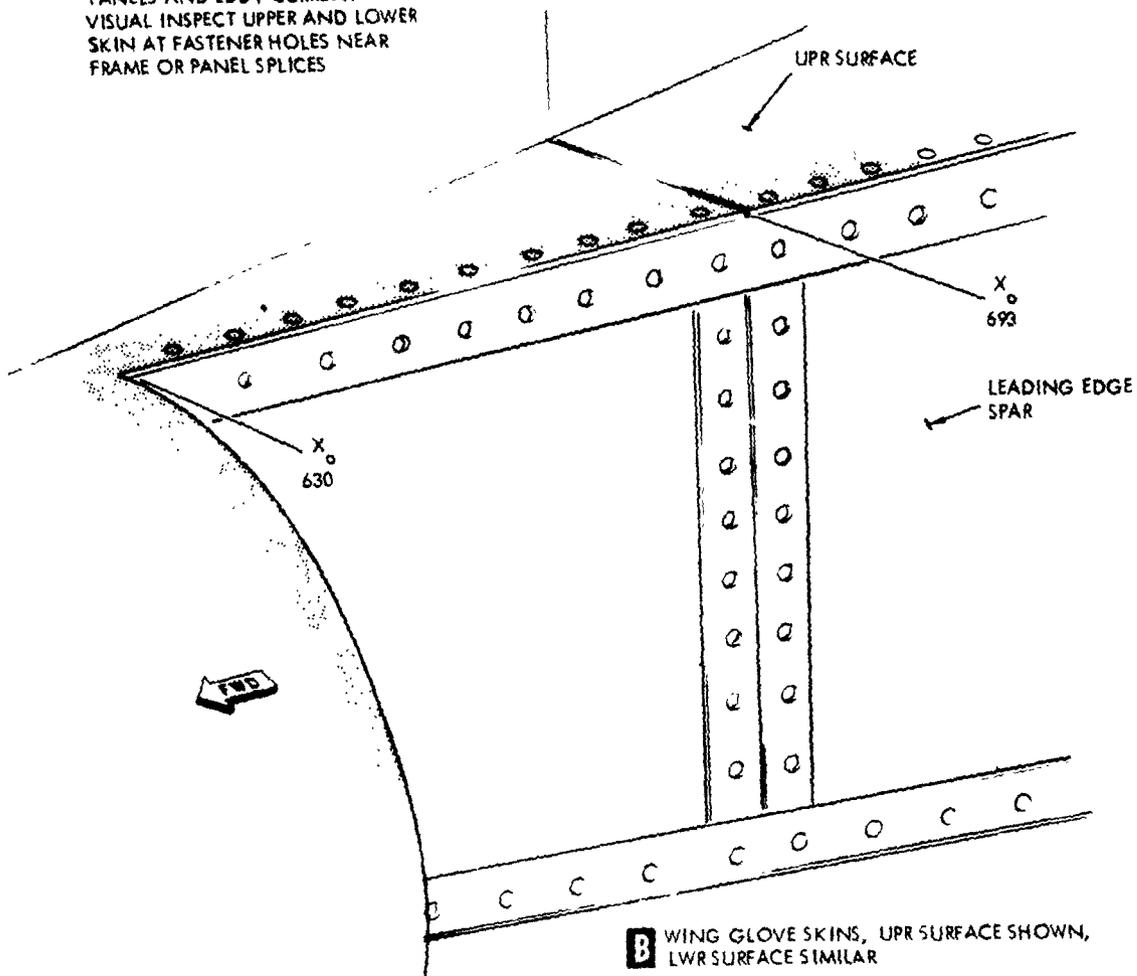
ACCESS: Remove leading edge access panels top and bottom from X_o 626 to X_o 800.

NDT TECHNIQUES: Primary: Eddy Current (para. 1.5.4.4) and visual
Backup: Penetrant (para. 1.5.2.1 Fig. 1-9)



WING GLOVE FAIRING
L.H. SHOWN, R.H.
OPPOSITE

REMOVE LEADING EDGE ACCESS
PANELS AND EDDY CURRENT/
VISUAL INSPECT UPPER AND LOWER
SKIN AT FASTENER HOLES NEAR
FRAME OR PANEL SPLICES



B WING GLOVE SKINS, UPR SURFACE SHOWN,
LWR SURFACE SIMILAR

Figure 3-3. Glove Fairing Skins

PROCEDURE NO. 3-404, Figure 3-4

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: SIDE PANELS

DRAWING(S): 70Z103
VL72-000028 (PRR)

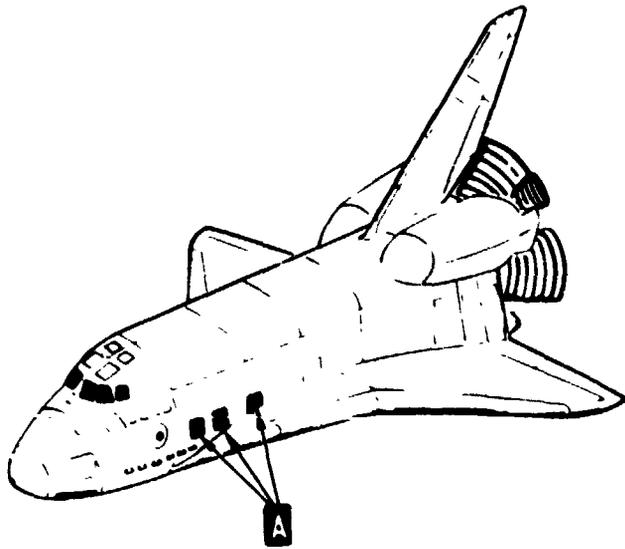
COMPONENT/AREA DESCRIPTION: MID-FUSELAGE ACCESS OPENINGS,

There are three rectangular access openings on each side of the mid-fuselage which provide personnel access for maintenance and servicing of systems ECLSS and others. They are: (1) the mid-fuselage maintenance and ECLSS servicing access openings centered at Z_o 350, X_o 599 (LH), X_o 617 (RH), X_o 651 (LH) and X_o 672 (RH); Z_o 356, X_o 824. Because these openings are penetrations into primary load carrying structure, stress concentrations at the corners of these openings may cause fatigue damage in these areas. The structure is composed of 2024 aluminum alloy, finished with zinc chromate primer and Supercorapon 515-700 paint, and covered externally by LHRI/TPS panels.

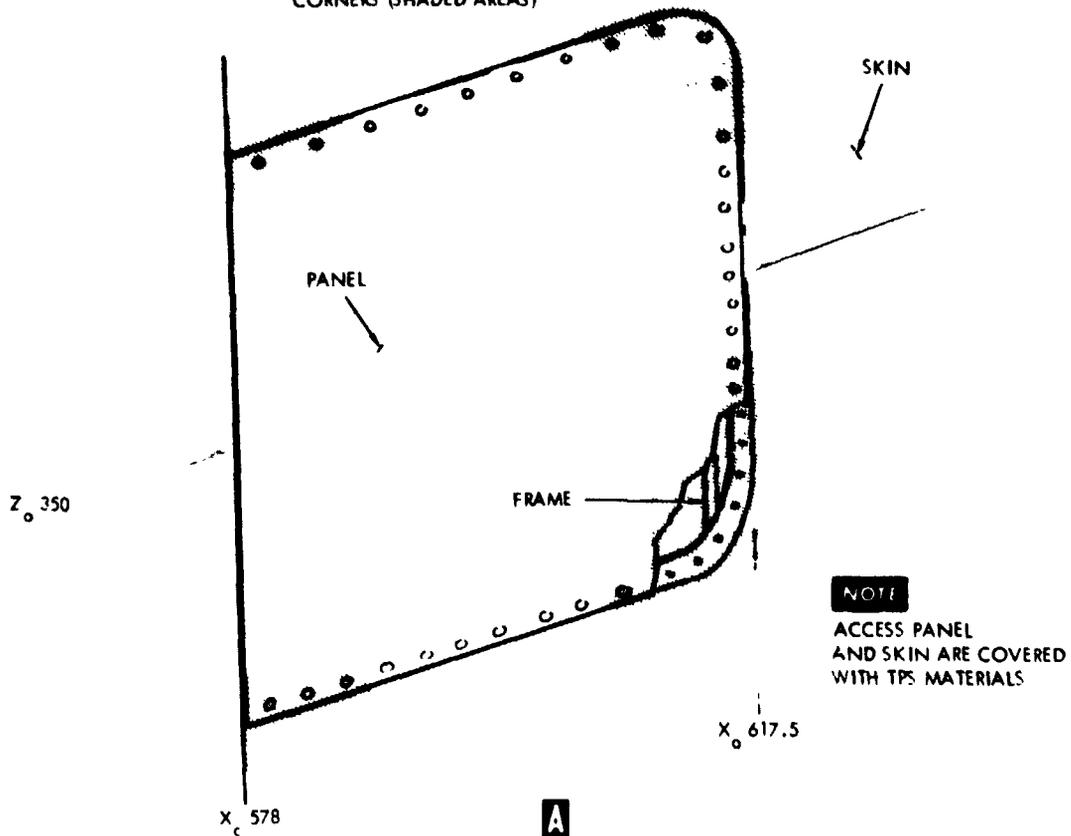
DEFECTS: Cracks may occur at the (upper and lower, forward and aft) corners of the structure forming the frame of the openings, originating at fastener holes or in the interior corner edges. The cracks should be inspected on the interior and exterior surfaces of the frame structure.

ACCESS: Remove the respective maintenance/access panels. Inspect from outside the fuselage or enter the cargo bay.

NDT TECHNIQUES: Primary: Eddy current (see para. 1.5.4.4)
Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



INSPECT INTERIOR STRUCTURE
AND SKIN AT ACCESS OPENING
CORNERS (SHADED AREAS)



TYPICAL MID-FUS EQUIPMENT
ACCESS PANEL, THREE EACH
SIDE UP FUSELAGE

Figure 3-4. Mid-Fuselage Access Openings

PROCEDURE NO. 3-405, Figure 3-5

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: RADIATOR PANELS

DRAWING(S): MC621-0039; VL72-000027

COMPONENT/AREA DESCRIPTION: FWD ECS RADIATOR PANEL HINGES.

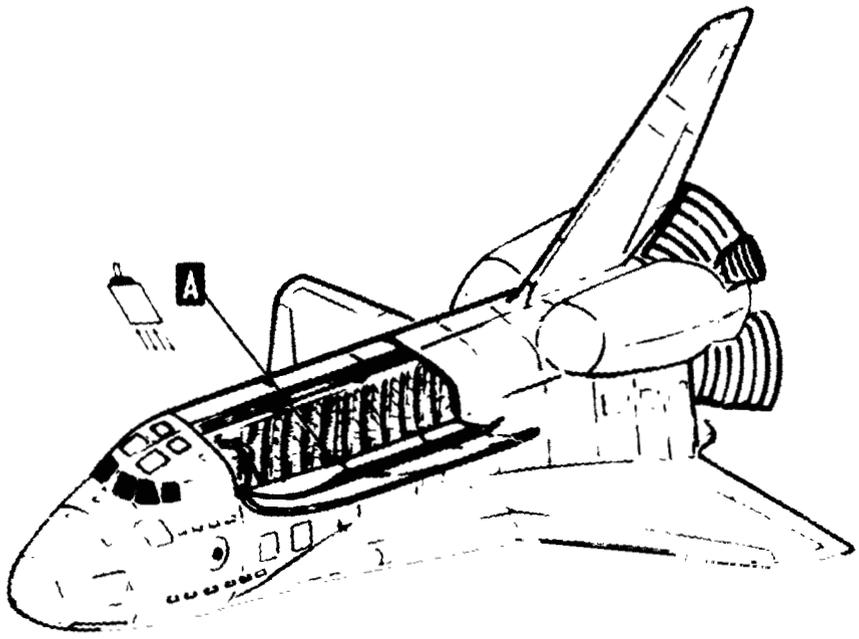
The ECS radiator panels are structurally supported at the inner surface of the payload doors and are deployed by opening the payload doors in orbit. There are two radiator panels per payload door section (four per side), hinged to the mid-fus hinge longeron only on the fwd door sections. Each panel on the fwd door section has two hinges which are made of titanium-6Al-4V alloy. The hinges may be susceptible to damage since the longeron by which they are supported also react fuselage torsional loads, support flight and purge pressure loadings at $Y_{\circ} \pm 105$, $Z_{\circ} 410$, and fus stations $X_{\circ} 621, 692, 805, \text{ and } 875$. Aft radiator panels are structurally attached to the payload doors and have no hinges.

DEFECTS: Cracks may occur in the bolt holes where the hinge mechanism attach to the hinge longeron and radiator panels, and at the hinge pivot joints.

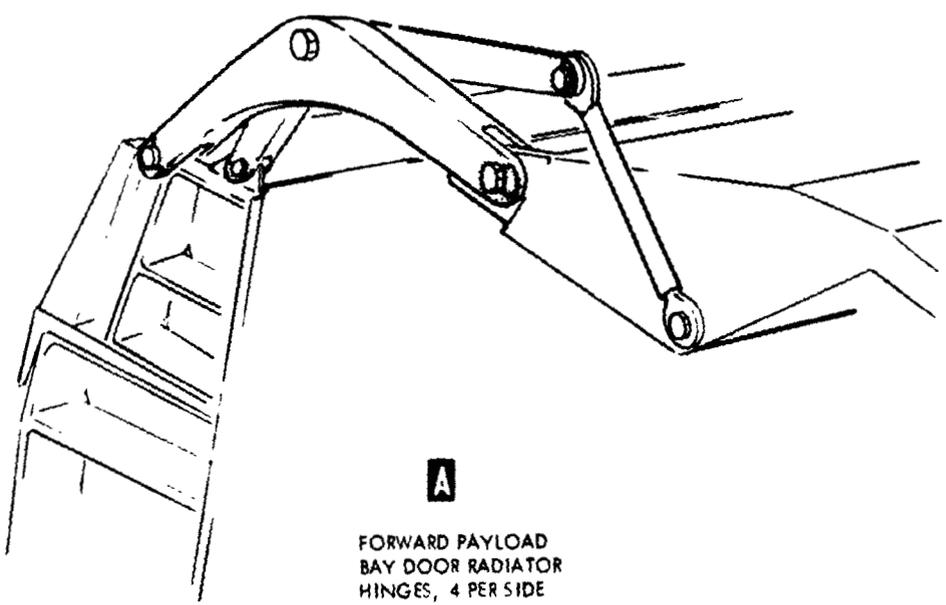
ACCESS: Open the payload doors to (TBD) degrees using GSE to support the doors and use a suitable work platform. Need to remove radiator panels and/or disassemble hinge mechanism for inspection not determined, but should not be necessary for primary inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for hinge pivot joints, eddy current (para. 1.5.4.4) for hinge-longeron/radiator attachment areas.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



INSPECT AROUND PIN HOLES
AT HINGE POINTS



FORWARD PAYLOAD
BAY DOOR RADIATOR
HINGES, 4 PER SIDE

Figure 3-5. Forward ECS Radiator Panel Hinges

PROCEDURE NO. 3-406, Figure 3-6

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: SIDE PANELS

DRAWING(S): 70Z1815 CONVAIR Fig. 1.4.3
(73MA5769) VL72-000028 "B"

COMPONENT/AREA DESCRIPTION: FRAME CORNERS, WHEEL WELL FUSELAGE INNER/OUTER ACCESS OPENINGS. The access opening in the mid-fuselage, wheel well area, is centered at $X_o = 1055$, $Y_o = 105$, $Z_o = 296$. Since the opening is a penetration into highly loaded primary structure, stress concentrations, around the opening may eventually result in fatigue damage to the frame, stringers and/or fittings used to form the opening sill. The material of construction is 2024 aluminum alloy with a zinc chromate primer and Supercorapon 515-700 finish.

DEFECTS: Edge cracks and cracks around fastener holes in the attachment areas at the corners of the sill frame structure; also in the webs of corner attachment fittings.

ACCESS: Access is attained by entering the MLG wheel well and removing the panel which normally closes the Wheel-Well fuselage access opening.

NDT TECHNIQUES: Primary: Eddy current (para. 1.5.4.4)
Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)
requires paint stripping.

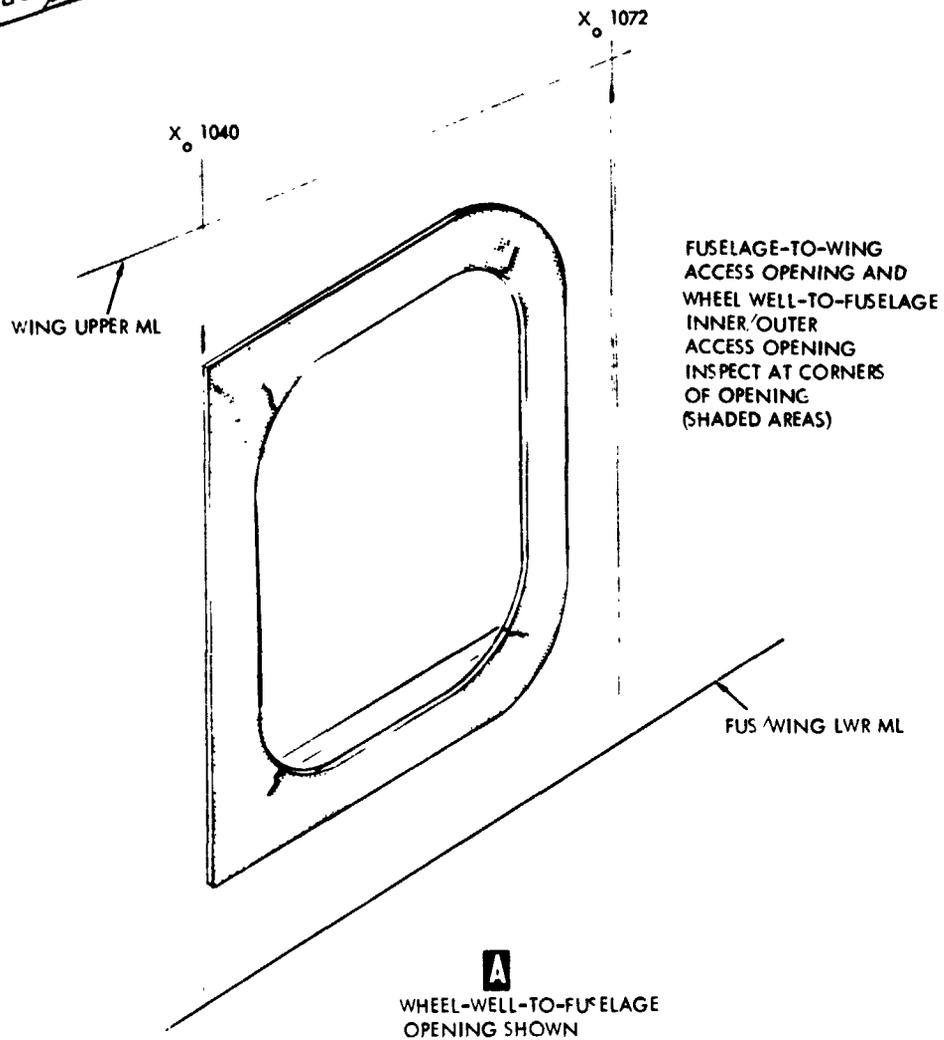
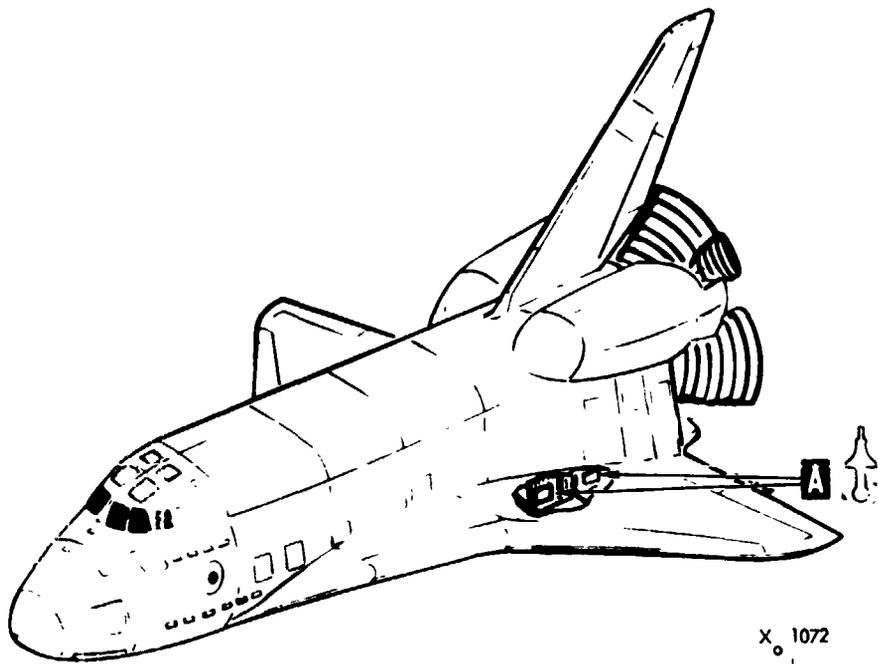


Figure 3-6. Frame Corners, Inner/Outer Access Opening

PROCEDURE NO. 3-407, Figure 3-7

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: MID-FUS LOWER SKIN PANELS

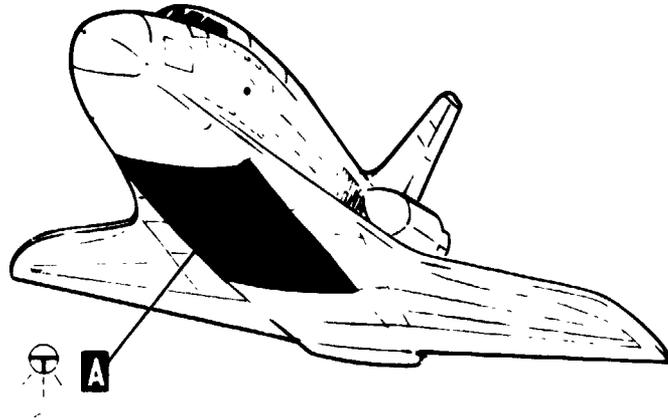
DRAWING(S): 70Z1033 (Convair)

COMPONENT/AREA DESCRIPTION: LOWER SKIN PANELS. The mid-fuselage lower skin panels are made from 2124-T851 aluminum alloy machined plate. The skins are located along the bottom of the fuselage, extending from $X_{\circ} 578$ to $X_{\circ} 1191$ and from $Y_{\circ} (\pm)105$ to $Y_{\circ} (-)105$. Compressive tensile and torsional loads due to tail-down landing and gust loads may produce damage in certain areas. The skin panels should be inspected along transverse splices at $X_{\circ} 578$, $X_{\circ} 919$ and $X_{\circ} 1191$; and longitudinal splices at $Y_{\circ} \pm 105$ and $Y_{\circ} 0.0$; and around cut-outs.

DEFECTS: Through-cracks at rivet/fastener holes along the splices and around the periphery of cut-outs.

ACCESS: TPS materials cover the exterior surface of these panels. Access for placing film is obtained by entering the mid-fuselage underfloor crawl space.

NDT TECHNIQUES: Primary: X-ray radiography (para. 1.5.6.2) along all areas.
Backup: Remove local TPS in suspect areas and use eddy current surface probe (para. 1.5.4.4)



PLACE X-RAY TUBE OUTSIDE FUSELAGE

PLACE X-RAY FILM NEXT TO SKIN
INSIDE FUSELAGE IN UNDERFLOOR
AREA

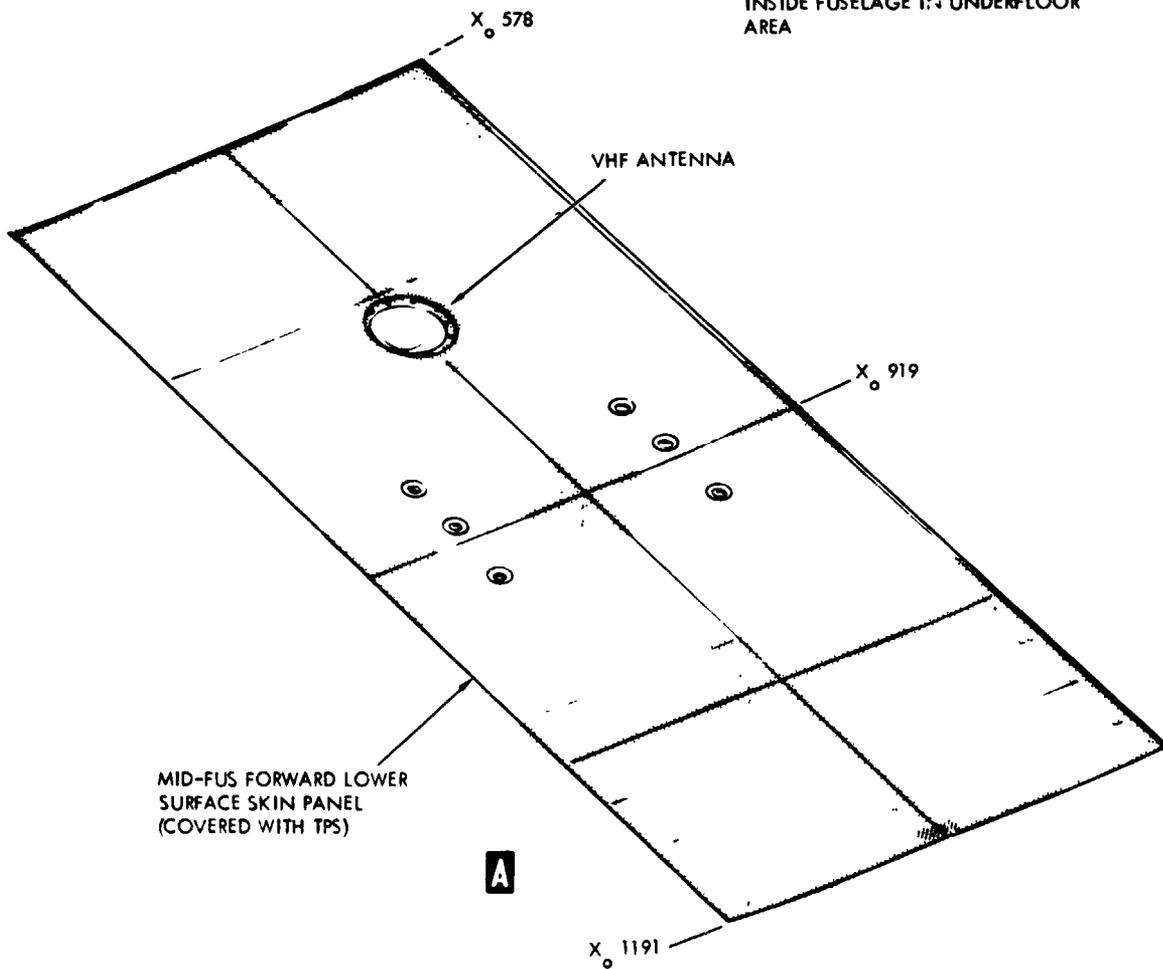


Figure 3-7. Mid-Fuselage Lower Skin Panels

PROCEDURE NO. 3-408, Figure 3-8

	<u>TYPE INSPECTION</u>
<u>MAJOR ASSEMBLY:</u> ORBITER, MID-FUSELAGE, ZONE 4	(X) POSTFLIGHT
<u>SUBASSEMBLY:</u> PAYLOAD BAY DOOR HINGES	
<u>DRAWING(S):</u> MC621-0039; VL70-004015; VL70-004008	
<u>COMPONENT/AREA DESCRIPTION:</u> PAYLOAD DOOR POWER HINGES.	

The payload doors are hinged to fittings mounted on the mid-fuselage sill longerons. The payload doors are split longitudinally along the Orbiter centerline and also into fore and aft sections, so that there are four door sections hinged at $Y_{\circ} \pm 105$ and $X_{\circ} 420$. Each full door contains three power hinges on each side of the fuselage located at fuselage stations $X_{\circ} 602$, 737, and 902; fwd; the aft door contains power hinges at $X_{\circ} 996$, 1144, and 1264. Each door section contains two door drive units for powering the hinges via a torque tube drive assembly. The power hinges are made of titanium-6Al-4V. Since the payload doors react fuselage torsional loads, support flight and purge pressure loads, structurally support the radiator panels and react thermo-mechanical loads, the hinges may become damaged.

DEFECTS: Cracks at the bolt holes where the hinge mechanisms attach to payload door, sill longeron and power shaft.

ACCESS: Open the payload doors to (TBD) degrees using GSE to support the doors and use a suitable work platform. (need to disassemble hinge mechanism for inspection not determined).

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C).
Backup: Penetrant (para. 1.5.2.1 Fig. 1-9)

PROCEDURE NO. 3-409 , Figure 3-3

<u>MAJOR ASSEMBLY:</u>	ORBITER, MID-FUSELAGE, ZONE A	<u>TYPE INSPECTION</u> (X) POSTFLIGHT
<u>SUBASSEMBLY:</u>	PAYLOAD BAY DOOR HINGES	
<u>DRAWING(S):</u>	MC621-0039, VL70-004015	
<u>COMPONENT/AREA DESCRIPTION:</u>	PAYLOAD DOOR IDLER HINGES.	

The payload bay doors are hinged to fittings mounted on the mid-fuselage sill longerons. The payload doors are split longitudinally along the Orbiter centerline and also into fore and aft sections, so that there are four hinged door sections. The payload bay contains 9 titanium -6AL-4V alloy idler hinges and 4 shear hinges on each side of fuselage that operate in conjunction with 6 power hinges. The idler hinges are located at $Y_o \pm 105$, $Z_o 420$ and fuselage stations $X_o 670, 737, 784, 851, 1033, 1100, 1144, 1204,$ and 1297. The shear hinges are at fus stations $X_o 602, 919, 966$ and 1264. Since the payload doors react fuselage torsional loads, support their own flight and purge pressure loadings, provide structural support for the radiator panels, and react thermo-mechanical loads, the hinges may become damaged.

DEFECTS: Cracks may occur in the bolt holes where the hinge mechanism attaches to longeron sill and payload doors.

ACCESS: Open the payload doors to (TBD) degrees using GSE to support the doors and use a suitable work platform. (Need to disassemble hinge mechanism for inspection not determined).

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C) and fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).

Backup: Eddy current bolt hole (para. 1.5.4.3).

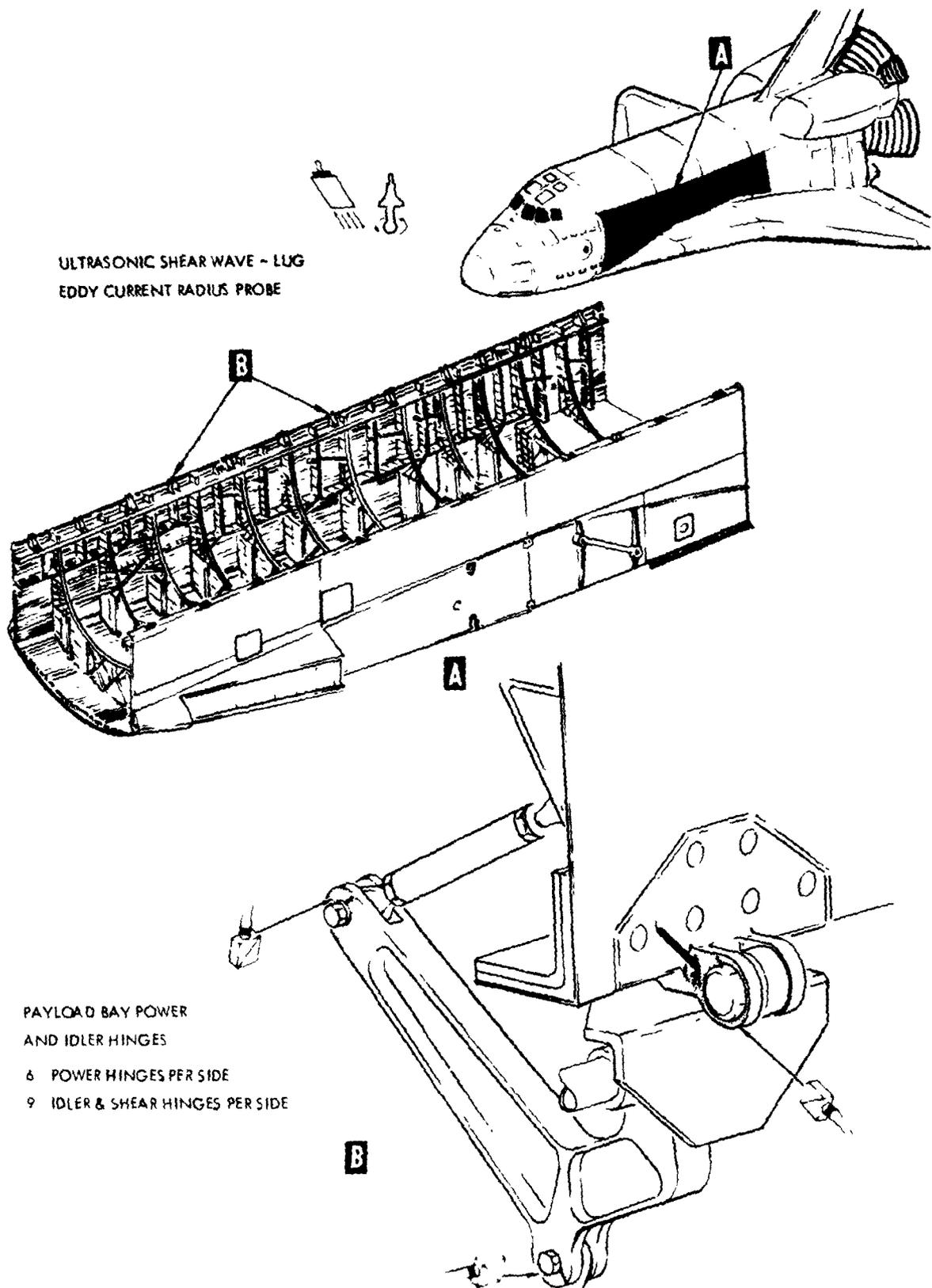


Figure 3-8. Payload Bay Power and Idler Hinges

PROCEDURE NO. 3-410, Figure 3-9

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

(X) POSTFLIGHT

SUBASSEMBLY: PAYLOAD BAY

DRAWING(S): VL72-000027B (PRR)
VL70-000044 (PRR)

COMPONENT/AREA DESCRIPTION: PAYLOAD SIDELOAD RETENTION

FITTINGS: Fourteen (?) payload tie-down fittings are located along the payload bay floor centerline ($Y_{\circ} = 0.0$, $Z_{\circ} = 310$) and along the payload bay sill at $Z_{\circ} = 419$, $Y_{\circ} = 100$. They are in the floor or sill longeron of the mid-fuselage and have provisions for securing the payload during all flight regimes. The fittings are made of (TBD) and have a TBD surface finish. They are primarily loaded by G-forces during ascent, re-entry, atmospheric flight and landings.

DEFECTS: Cracks may occur at the base of the receptacle and at the upper or lower outboard web-to-flange transitions on the fitting.

ACCESS: Enter the payload underfloor crawl space and locate each fitting along the fuselage centerline.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3) or eddy current (para. 1.5.4.4) for receptacle.

Backup: Fluorescent Penetrant (para. 1.5.2.1 Fig. 1-9)

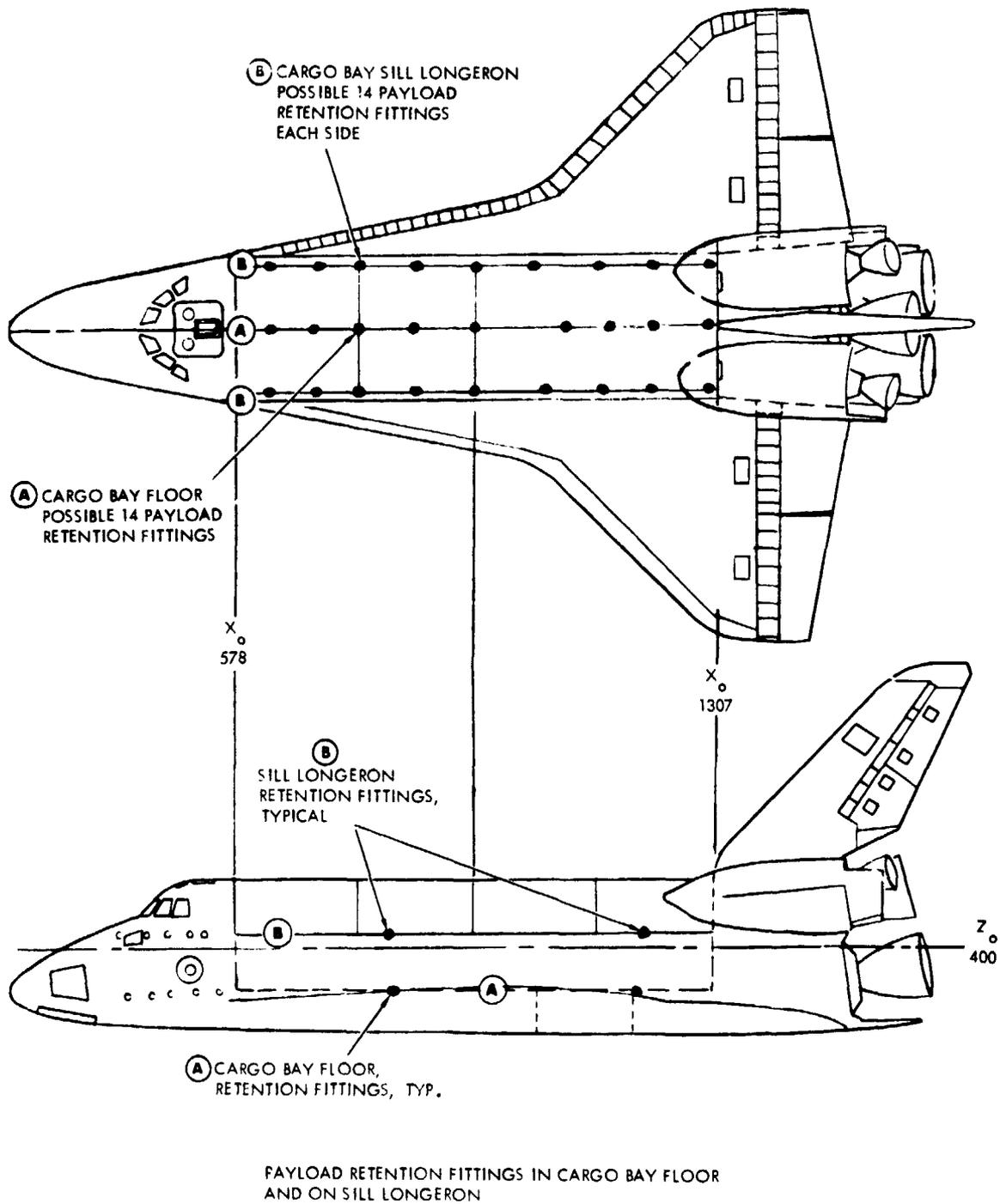


Figure 3-9. Payload Bay Sideload Retention Fittings

PROCEDURE NO. 3-411, Figure 3-10

<u>MAJOR ASSEMBLY:</u>	ORBITER, MID-FUSELAGE, ZONE 4	<u>TYPE INSPECTION</u>
<u>SUBASSEMBLY:</u>	MID FUS SIDE SKIN PANELS	(X) POSTFLIGHT
<u>DRAWING(S):</u>	70Z1019 (Convair)	

COMPONENT/AREA DESCRIPTION: SIDE SKIN PANELS. The mid fuselage side panels are made of 2124-T851 aluminum alloy machined plate. The panels are located along the side of the cargo bay from X₀ 578 to X₀ 1307 and extend from the lower edge to the cargo bay door hinge line (Y₀ 268 to Y₀ 410). The panels should be inspected along all vertical/transverse splices located at X₀ 578, X₀ 810, X₀ 1040, X₀ 1191, and X₀ 1307; in the vicinity of the wing-to-fuselage clevis attach fittings; the longitudinal splice along Z₀ 409 at frame stations and vertical splices; and around all access openings and cutouts. Damage may occur due to shear, tensile, or torsional loads resulting from high-q boost, wind gusts, aerodynamic and thermomechanical forces.

DEFECTS: Through-cracks at rivet/fastener holes near splices and clevis attach fittings and at corners or edges of access openings and cut-outs.

ACCESS: TPS materials cover the skins from the wing upward to the payload bay doors. X-ray film can be placed inside or outside of payload bay - preferably inside adjacent to skin with payload bay liner removed. Areas below wing intersect line can be accessible by entering the wing or payload bay with liner removed.

NDT TECHNIQUES: Primary: X-ray radiography (para. 1.5.6.2) for areas above wing mold line where TPS reduces access. Areas below wing mold line can be inspected visually and by eddy current technique (para. 1.5.4.4).

Backup: Removal local TPS when crack is suspected and inspect with eddy current surface probe (para. 1.5.4.4)

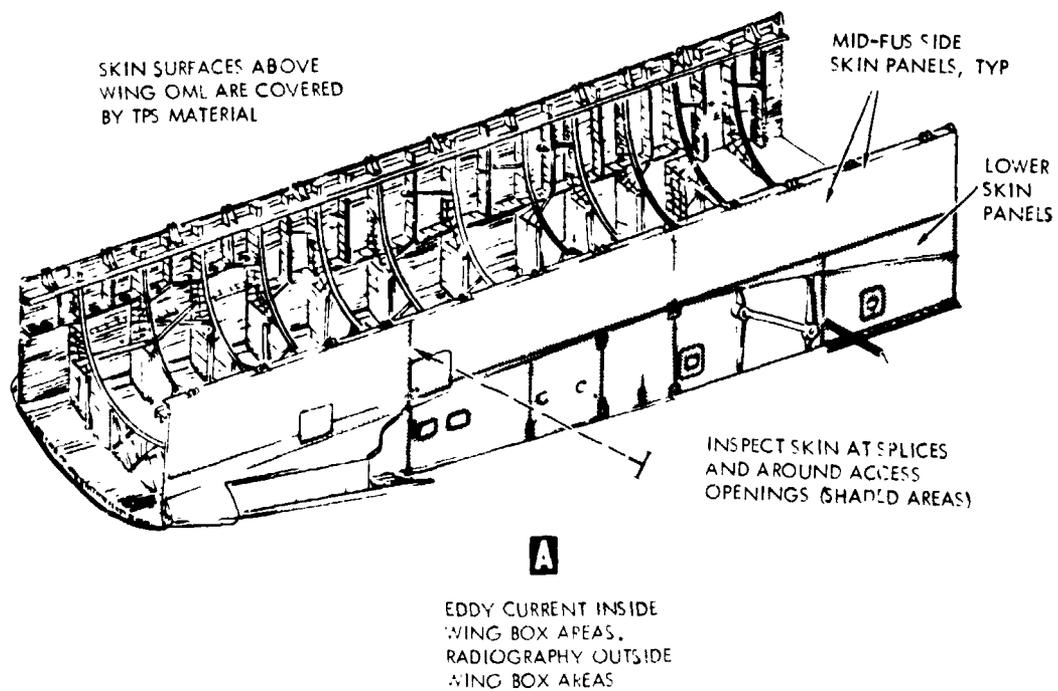
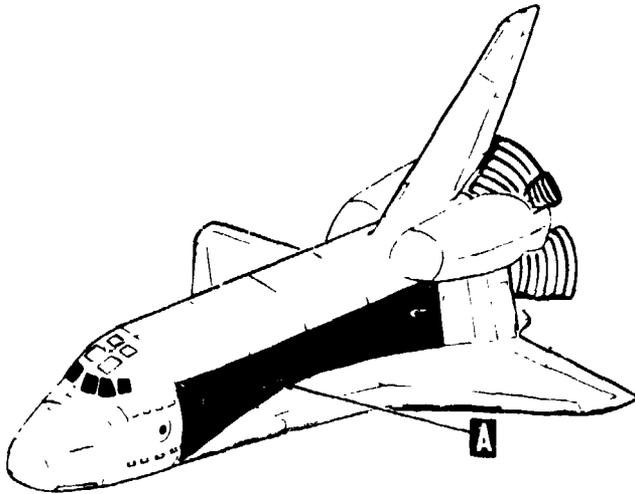


Figure 3-10. Mid-Fuselage Side Skin Panels

PROCEDURE NO. 3-412, Figure 3-11

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

(X) POSTFLIGHT

SUBASSEMBLY: MID FUS, LOWER SKINS

DRAWING(S): 70Z1024 (Convair)

COMPONENT/AREA DESCRIPTION: WING CARRY-THROUGH SKINS.

These panels, forming the bottom surface of the wing torque box, are machined from 2124-T851 aluminum alloy plate, and contain integral stiffeners. They are located between $X_{\circ} 1191$ and $X_{\circ} 1307$, and extend from $Y_{\circ} -105$ to $Y_{\circ} +105$. They receive tension and torsional loads from tail-down landings and aerodynamic forces which may produce damage along panel splice and attachment areas. Panel transverse splices at $X_{\circ} 1191$, $X_{\circ} 1249$, and $X_{\circ} 1307$ and longitudinal splices at the cargo bay sidewalls should be inspected.

DEFECTS: Corner or edge cracks at fastener holes in splice tangs. Cracks at runout of integral stiffeners.

ACCESS: Access for film placement is attained by entering the mid fus underfloor crawl space. TPS materials cover the lower panel surfaces. Local TPS and fastener must be removed to use back-up technique for suspect crack.

NDT TECHNIQUES: Primary: X-ray radiography (para. 1.5.6.2) for skin splices. Eddy current (para. 1.5.4.4) or ultrasonic (para. 1.5.5.3 C) for stiffener runouts.

Backup: Eddy current bolt hole (para. 1.5.4.3).

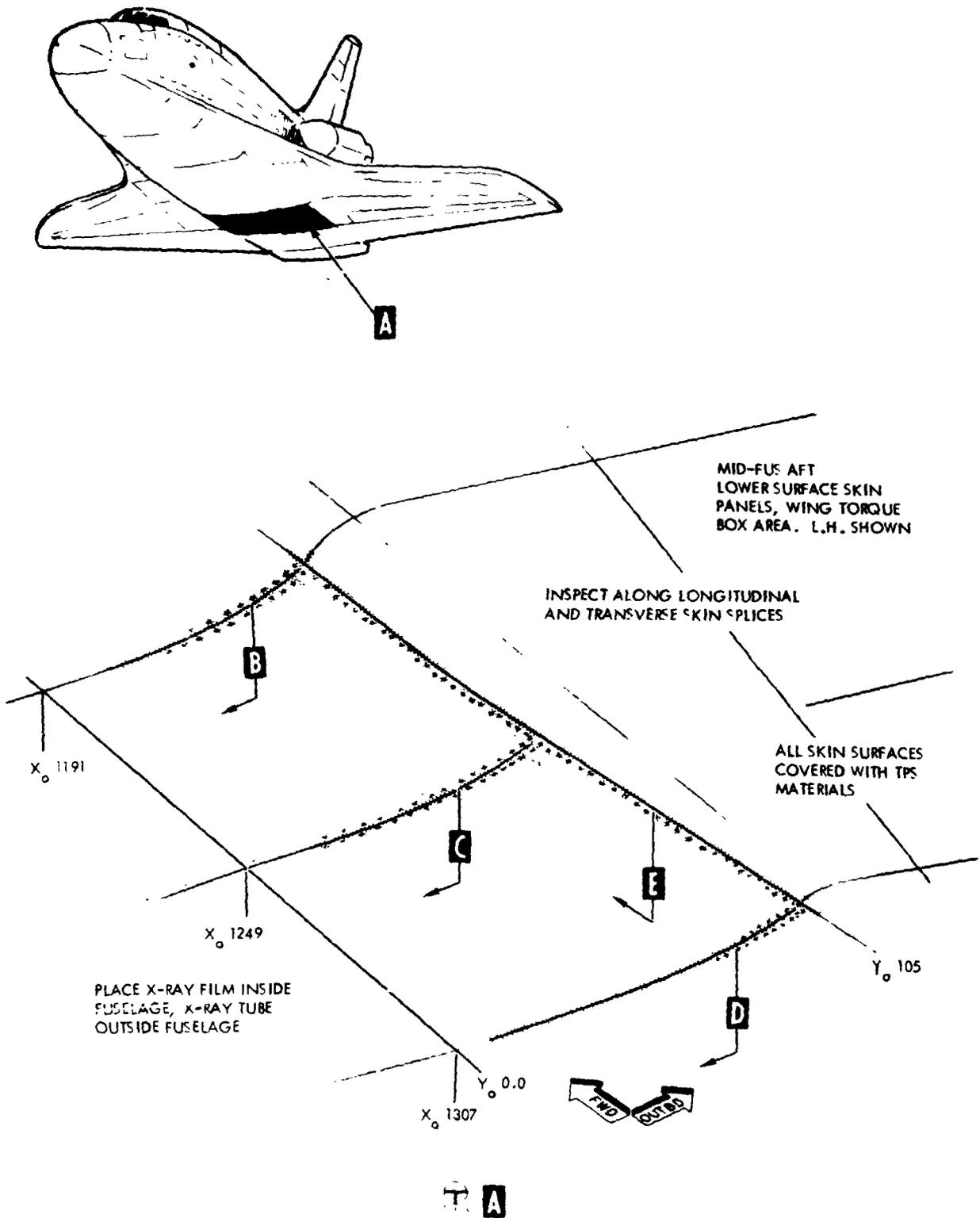


Figure 3-11. Mid-Fuselage Wing Carry-Through Skins (Sheet 1 of 2)

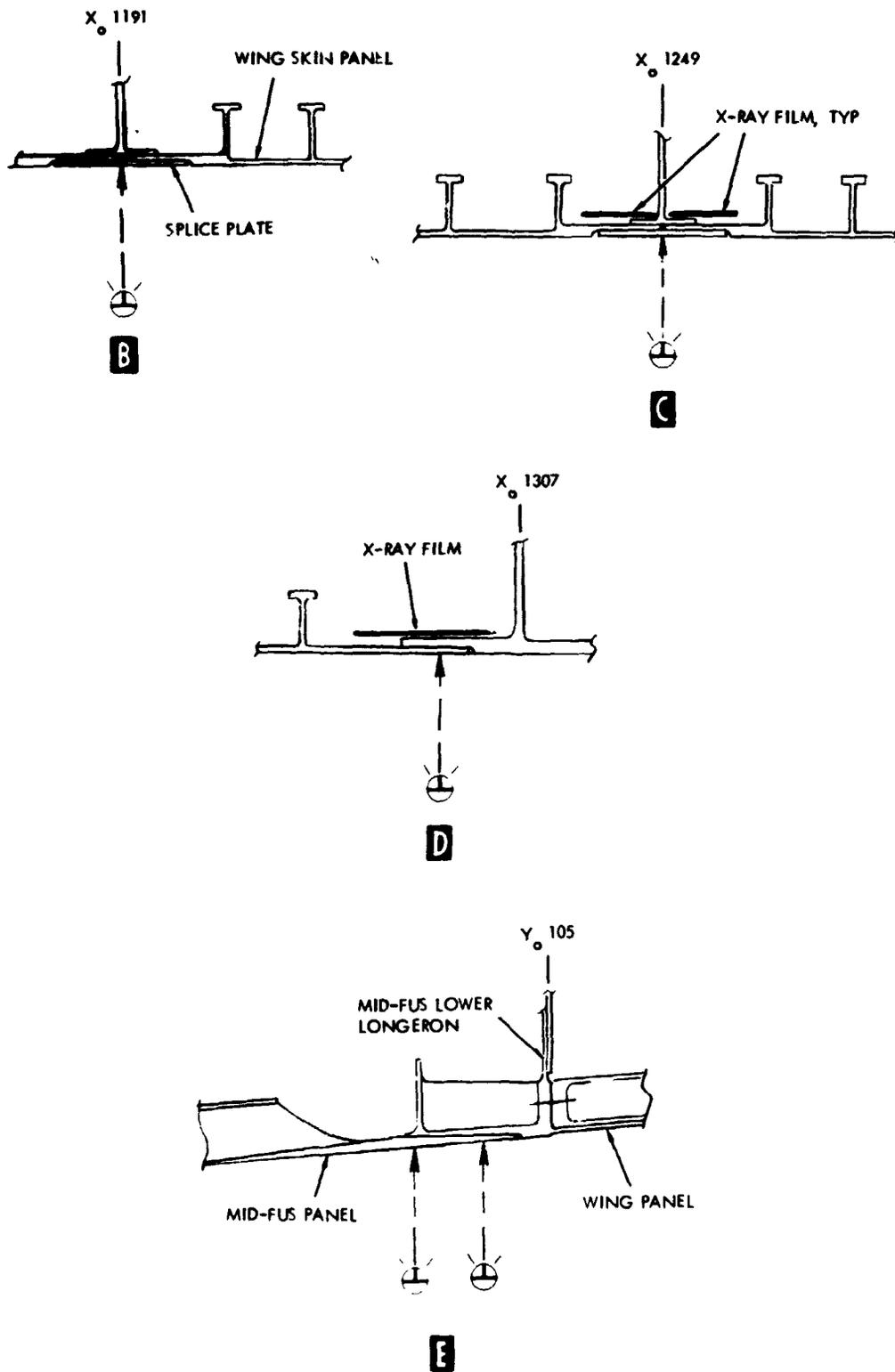


Figure 3-11. Mid-Fuselage Wing Carry-Through Skins (Sheet 2 of 2)

PROCEDURE NO. 3-413, Figure 3-12

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

(X) POSTFLIGHT

SUBASSEMBLY: MID-FUS FRAMES

DRAWING(S): 70Z1027A (Convair)

COMPONENT/AREA DESCRIPTION: WING CARRY-THROUGH SPAR FRAMES.

These frames are machined from 2124-T851 plate and are given a zinc chromate primer and Supercorapon 515-700 finish. The most critical load condition for these safe life components is bending during high-q boost and 2.5G maneuver. Fatigue damage could eventually result in splice areas of the frames. The wing torque box is integrally built into the mid-fuselage and contains two wing support frames and two intermediate frames in which wing loads are dominant. The description covers the two wing support frames at X_{\circ} 1191 and X_{\circ} 1249.

DEFECTS: Radial cracks at fastener holes in frame splice areas. Cracks generally oriented fore/aft.

ACCESS: Enter wing torque box area - mid-fuselage underfloor crawl space - thru access opening in aft-fuselage X_{\circ} 1307 bulkhead, frame splice areas are accessible on fore and aft sides of frame.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C) and/or eddy current surface probe (para. 1.5.4.4) (for cracks extending beyond fastener heads/nuts).

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).

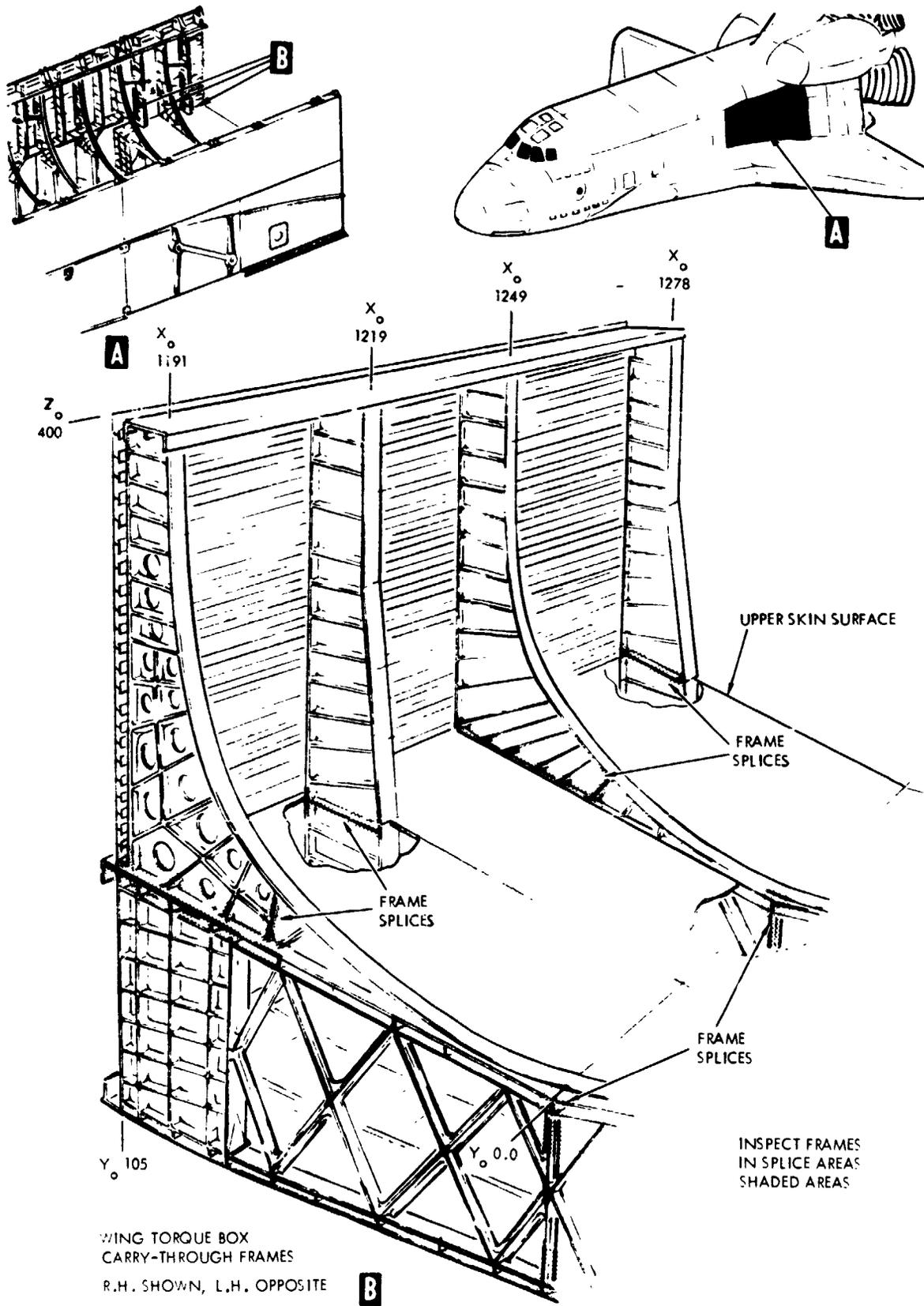


Figure 3-12. Wing Carry-Through Spar Frames

PROCEDURE NO. 3-414, Figure 3-13

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

(X) POSTFLIGHT

SUBASSEMBLY: MID-FUS LOWER LONGERON

DRAWING(S): Fig. 1.4.4 of 73MA5769

COMPONENT/AREA DESCRIPTION: WING-TO-FUSELAGE LWR AFT

LONGERON TENSION TIE. Located along the lower wing-to-fuselage attachment interface from Fus Sta X_o 1191 to Fus Sta X_o 1307 (Y_o ±105) are 72 tension bolts. Two tension bolts are installed in each of 36 riser bays on each side of the fuselage. The mated components include the 2024 aluminum alloy wing lower surface skin panels and the titanium alloy mid-fuselage lower aft longeron which have a zinc chromate primer and Supercorapon 515-700 paint finish. Tension/compression load spectra are transferred through the tension joint during all flight regimes.

DEFECTS: Fatigue cracks may occur around the tension bolt holes in either the wing skin or mid-fuselage longeron.

ACCESS: The holes are to be inspected on both sides of the interface. Enter the mid-fuselage crawl space through the MLG wheel well-fuselage access opening at X_o 1055, and enter the wing through the wing-to-fuselage aft access opening at X_o 1238. For backup inspection, the tension bolt in the suspect hole must be removed.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C)
Backup: Eddy current bolt hole (para. 1.5.4.3)

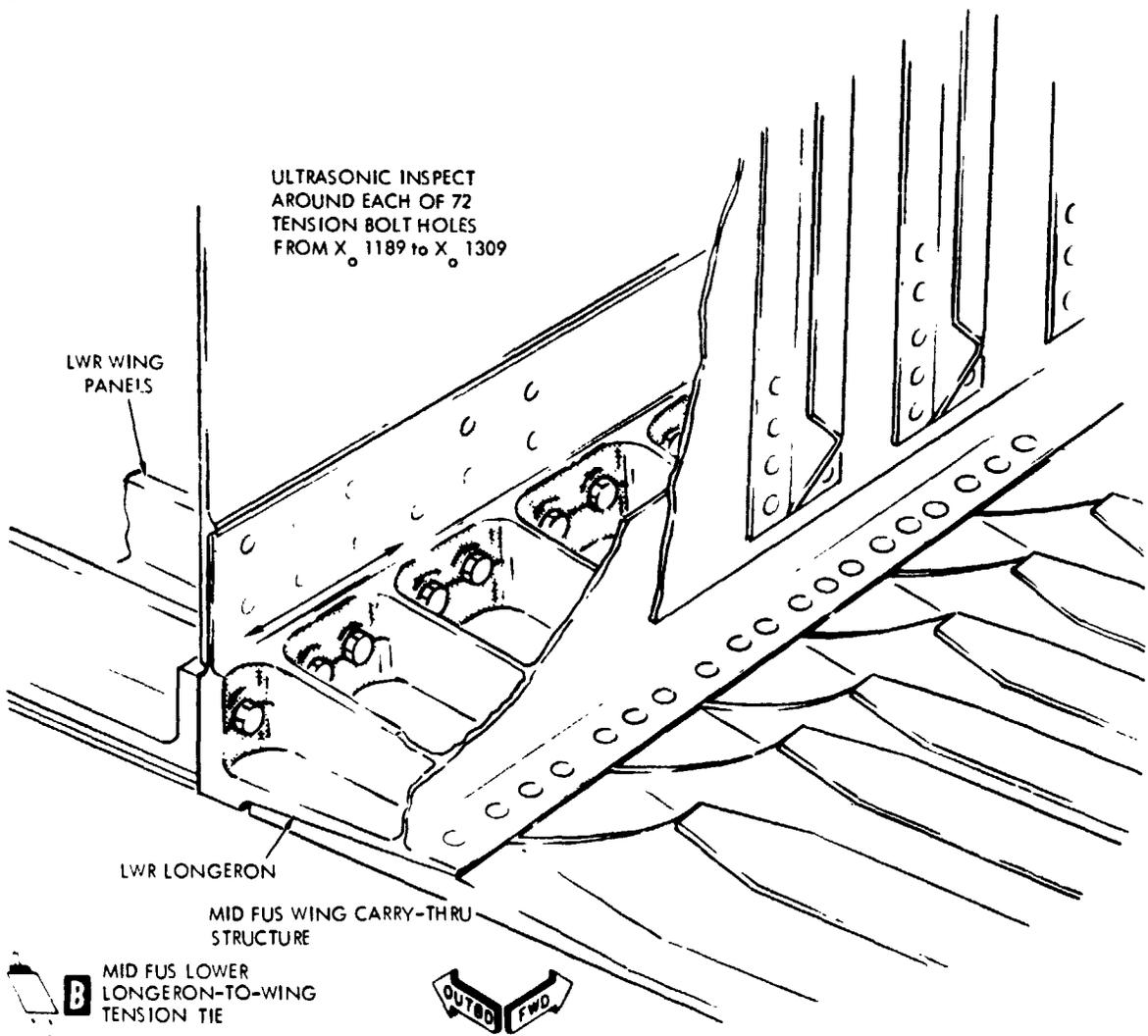
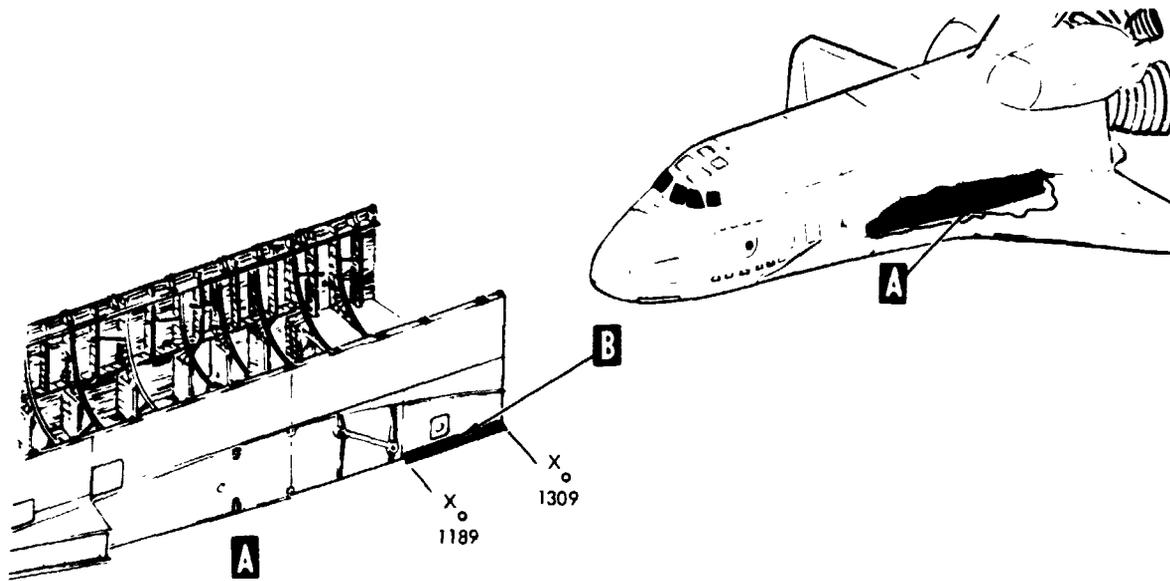


Figure 3-13. Wing/Fuselage Lower Aft Longeron Tension Tie

PROCEDURE NO. 3-415, Figure 3-14

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

(X) POSTFLIGHT

SUBASSEMBLY: MID-FUS LOWER LONGERON

DRAWING(S): 70X (Convair), (Fig. 1.4.4
73MA5769)

COMPONENT/AREA DESCRIPTION: MID-FUSELAGE LOWER AFT LONGERON.

The aft portion of the lower mid-fuselage longeron is made of 2124-T851 aluminum alloy (or titanium alloy) finished with a zinc chromate primer and Supercorapon 515-700 paint. It extends from $X_{\circ} 1278$ to $X_{\circ} 1075$ where it is spliced to a forward section. The longeron interfaces with the aft fus attach fitting at a splice at $X_{\circ} 1278$ using three 1-inch diameter bolts. It also mates with the wing carry-thru skin panels and aft side skin panels and attaches to the wing lower skin panels. The longeron attaches to the main wing box lower skin panels through 54 tension bolts along the $Y_{\circ} \pm 105$ butto line. The longeron experiences compression, tension, torsional and bending loads from fuselage flight loads and wing flexure.

DEFECTS: Horizontal and vertical cracks around the splice bolt holes at $X_{\circ} 1278$; cracks around fastener holes at the longeron splice at $X_{\circ} 1075$.

ACCESS: Access is gained by entering the mid-fus underfloor crawl space for longeron splice inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C)
(Fastener holes at non-splice areas are covered by radiographic inspection of wing carry-thru lower skin panel procedure).

Backup: Remove local suspect fastener or bolt and perform eddy current bolt-hole inspection (para. 1.5.4.3).

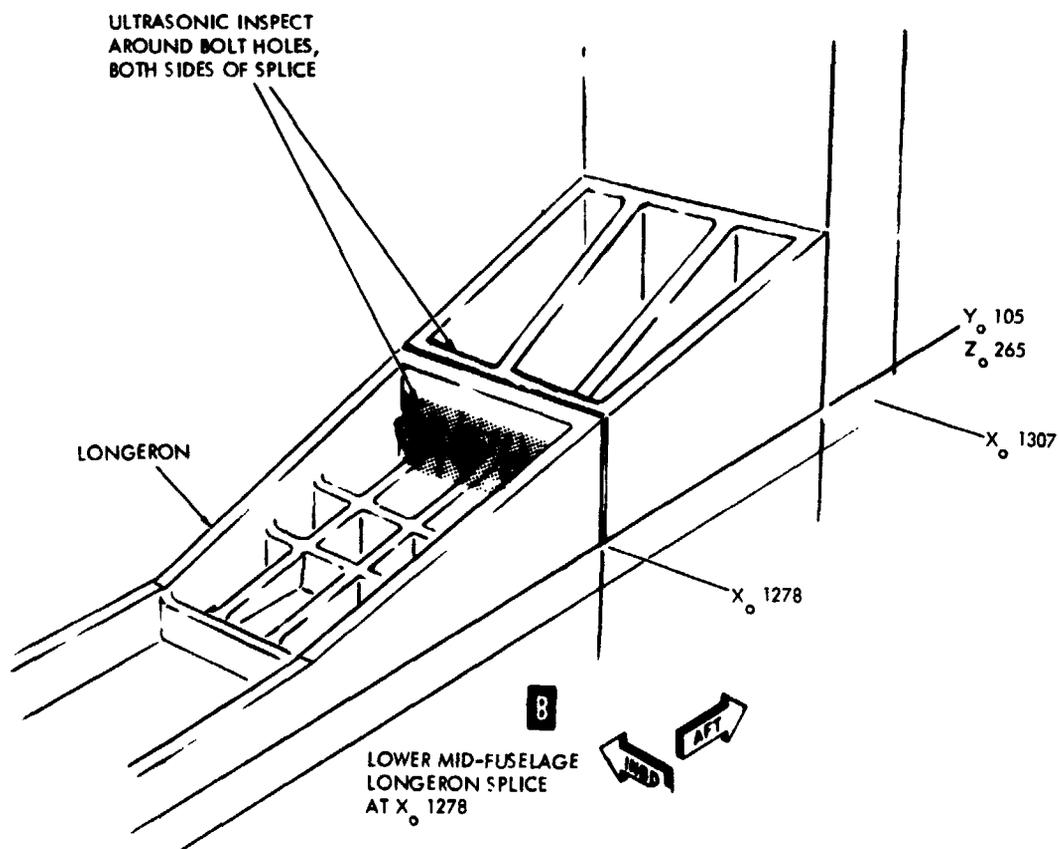
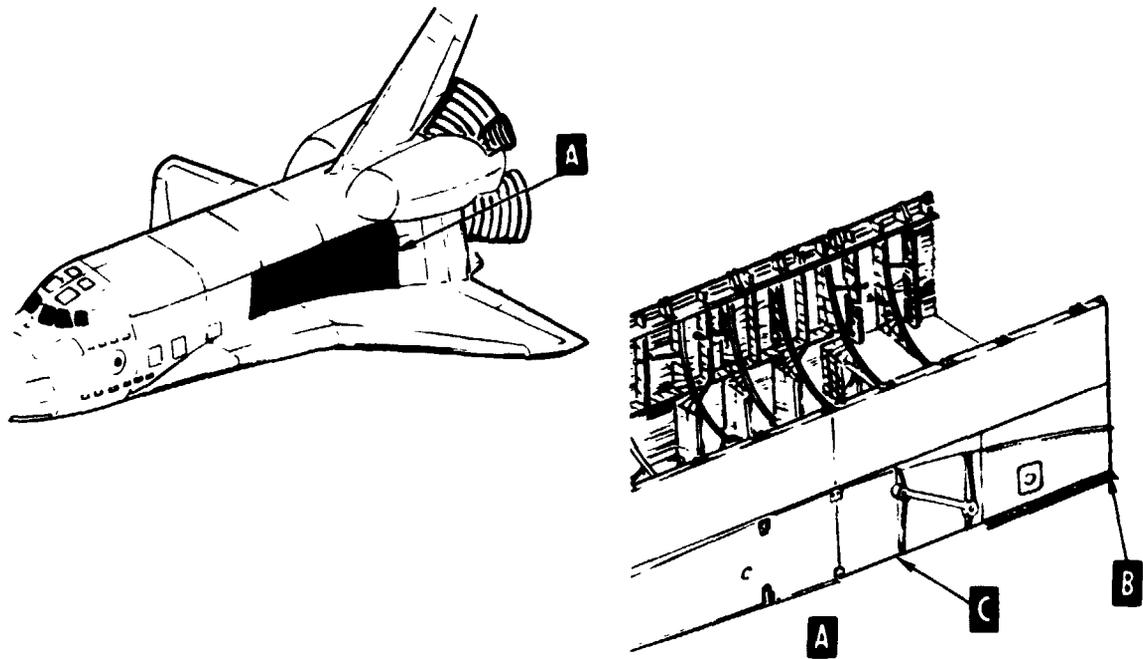


Figure 3-14. Mid-Fuselage Lower Aft Longeron (Sheet 1 of 2)

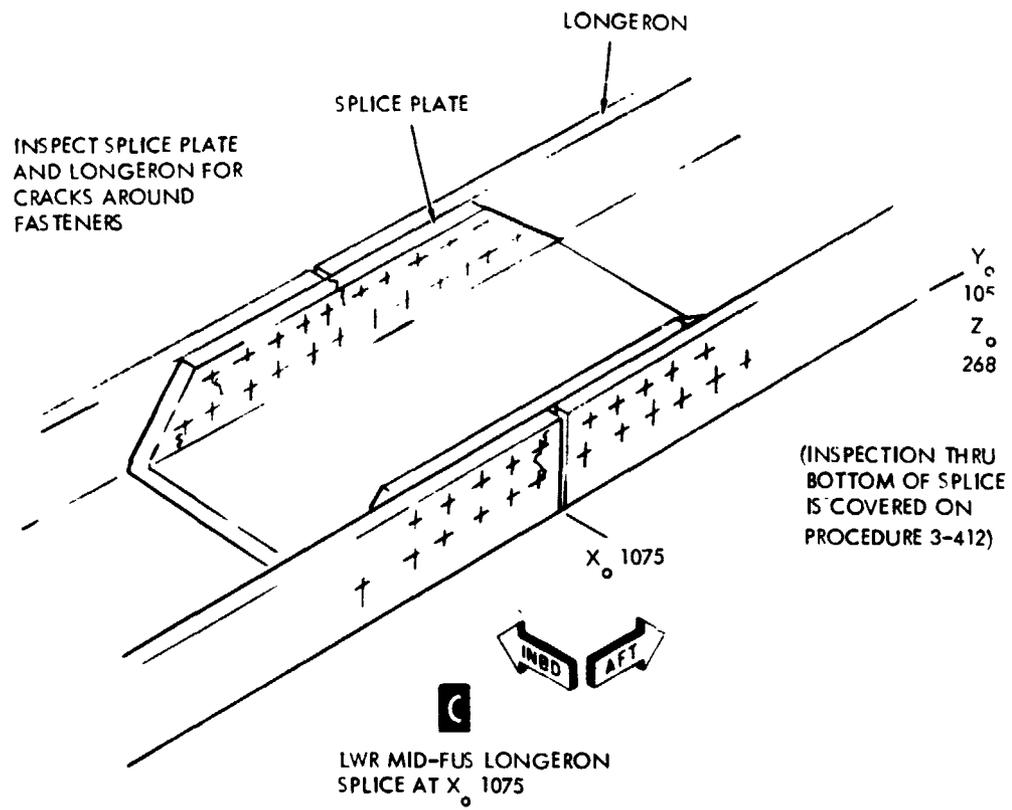


Figure 3-14. Mid-Fuselage Lower Aft Longeron (Sheet 2 of 2)

PROCEDURE NO. 3-416, Figure 3-15

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, MID-FUSELAGE,
ZONE 4

(X) POSTFLIGHT

SUBASSEMBLY: MID FUS SILL LONGERON

DRAWING(S): MC621-0006-3.1.1.1-1 (RI-Tulsa)

COMPONENT/AREA DESCRIPTION: PAYLOAD BAY AFT SILL LONGERON.

The aft sill longeron is machined from titanium-6Al-4V plate reinforced by boron/epoxy composite stiffeners. It is located just inboard of $Y_{\circ} \pm 105$, at $Z_{\circ} 410$ between $X_{\circ} 1191$ to $X_{\circ} 1299$ where it is spliced to the aft hoist/thrust shelf fitting. This portion of the sill longeron interfaces with the aft fuselage structure and is contained in the aft section of the payload bay shell. In this location, it reacts mid fuselage torsional, purge pressure, and compressive loads produced by engine thrust, aerodynamic bending moments, maneuver loads and internal/external pressure differentials.

DEFECTS: Horizontal cracks around bolt holes in longeron-to-aft fus splice at $X_{\circ} 1299$; cracks in fastener holes at fwd splice at $X_{\circ} 1191$.

ACCESS: From inside the cargo bay. Payload bay doors should be in open position, supported by GSE equipment.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C)
Backup: Eddy current bolt hole (para. 1.5.4.3) with suspect bolt removed.

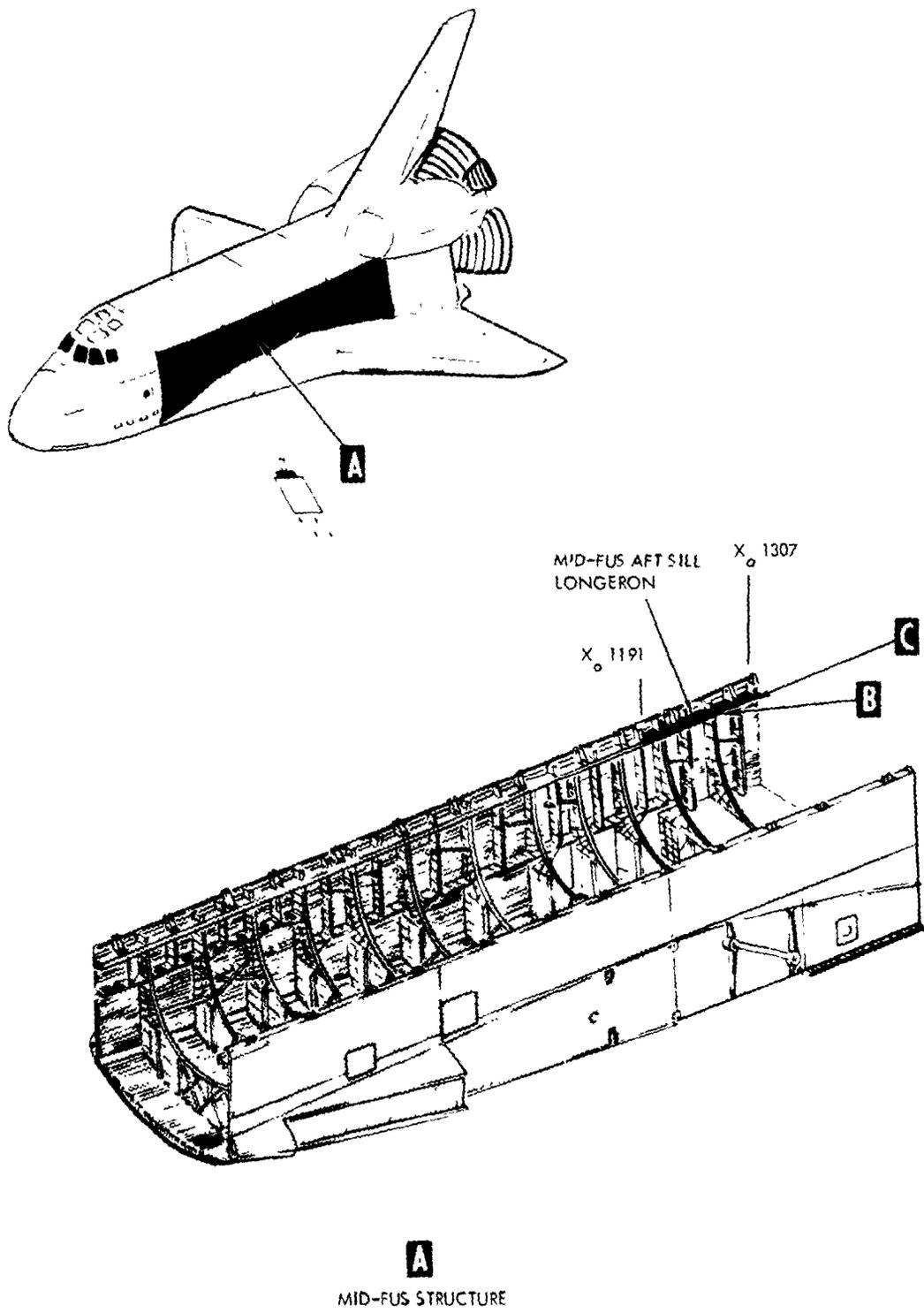


Figure 3-15. Payload Bay Aft Sill Longeron (Sheet 1 of 2)

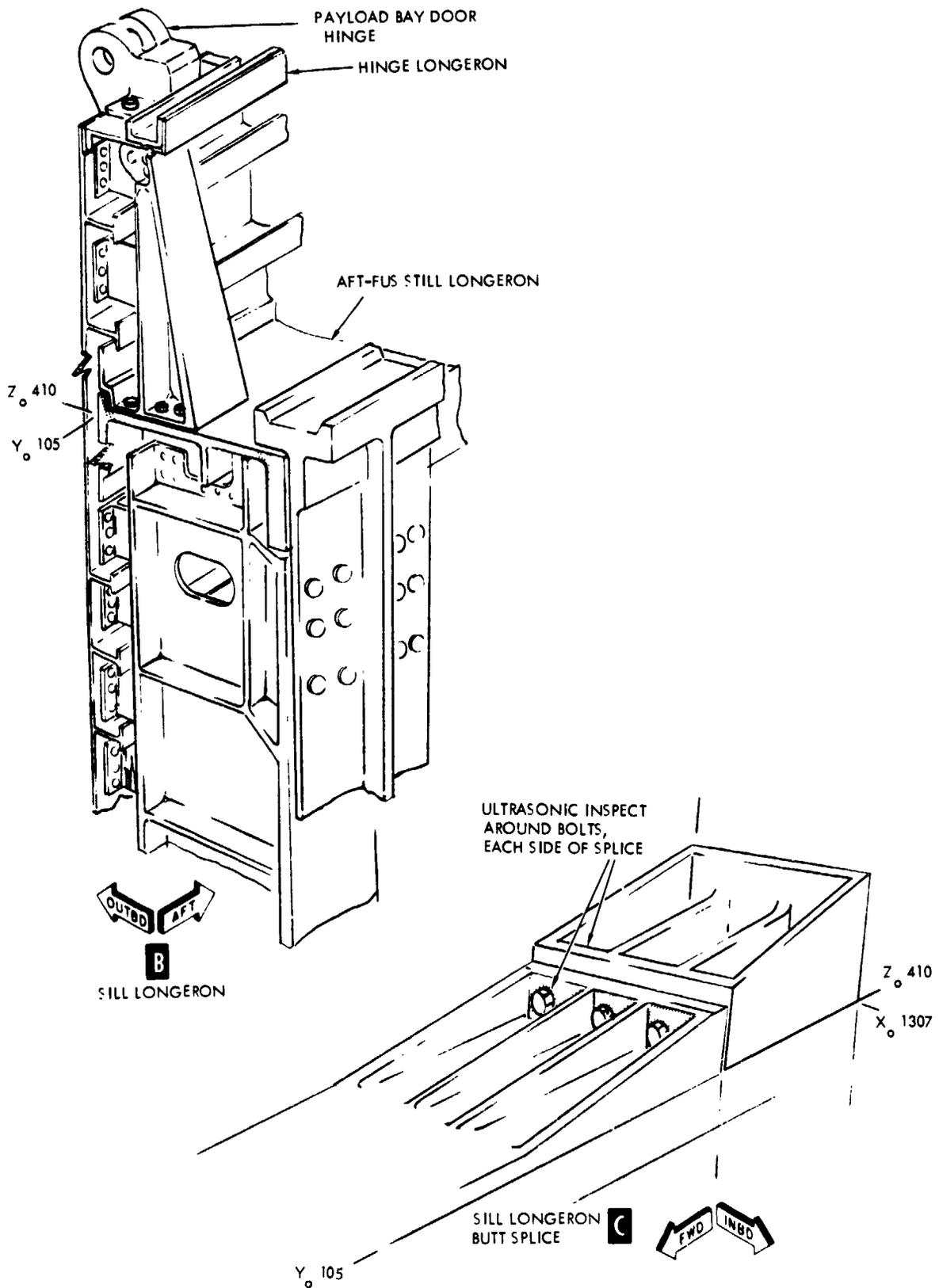


Figure 3-15. Payload Bay Aft Sill Longeron (Sheet 2 of 2)

SECTION 4. AFT FUSELAGE STRUCTURE

This section contains the NDE requirements for the aft fuselage shell structure, the thrust structure, and main engine mounts, vertical fin support, the OMS/RCS pods and engine mounts, the X_o 1307 bulkhead, aft ET/ORB attach fitting and the wing aft spar carry-through frame.

SECTION 4

TABLE OF CONTENTS

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
4-501	Aft Orbiter/ET Attach Fitting	4-1
4-502	Aft Jacking Points	4-4
4-503	Aft-Fuselage/Wing Spar Lower Attach Pads	4-6
4-504	Lower Thrust Shelf Attachment to X _o 1307 Bulkhead and Aft Fus Floor	4-8
4-505	Upper Thrust Shelf Attachment to X _o 1307 Bulkhead	4-10
4-506	Aft Hoist Point	4-12
4-507	Vertical Stabilizer Forward Spar-to-Fuselage Attach	4-15
4-508	Aft Fuselage Frames	4-17
4-509	Aft Fuselage Lower Skins	4-19
4-510	Wing Aft Spar Fuselage Carry-Through Frame at X _o 1365 and Floor Beam at X _o 1470	4-21
4-511	Upper Thrust Shelf Support Truss Attach	4-23
4-512	Lower Thrust Shelf Support Truss Attach	4-26
4-513	Boron Epoxy/Thrust Structure Bonds	4-29
4-514	Main Engine Gimbal Actuator Points	4-31
4-515	Main Engine Support and Gimbal Points	4-34
4-516	Lower Thrust Shelf and Main Engine Feedline Attachments	4-37
4-517	Upper Thrust Shelf and Main Engine No. 1 Feedline Support Attachments	4-39
4-518	Canted Frame, Lower Portion	4-41
4-519	Canted Frame, Upper Portion	4-44
4-520	Vertical Thrust Truss Attachments	4-47
4-521	Fin Support Frame, Clevis Attach Areas	4-51
4-522	Base Heat Shield Framing Structure	4-53
4-523	Base Heat Shield Dome Junctures	4-56

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SECTION 4 - TABLE OF CONTENTS (continued)

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
4-524	OMS Pod Attach Points to Aft Fuselage	4-58
4-525	Upper Longeron, OMS Deck	4-60
4-526	OMS Engine Gimbal Actuator Attach	4-62
4-527	OMS Engine Thrust Support Structure	4-65
4-528	Aft RCS Pod Attach Structure	4-68
4-529	Aft RCS Engine Mounts	4-70
4-530	Aft Body Flap Hinges	4-72
4-531	Aft Body Flap Hinge Spar/Rib Attach	4-74
4-532	Aft Body Flap Front Spar	4-76
4-533	Aft Body Flap Honeycomb Skin Panels	4-78

SECTION 4
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
4-1	Aft ET/Orbiter Attach Fitting	4-2
4-2	Aft Jacking Points	4-5
4-3	Aft-Fuselage/Wing Spar Lower Attach Pads	4-7
4-4	Lower Thrust Shelf Attachment to X _o 1307 Bulkhead and Aft Fuselage Floor	4-9
4-5	Upper Thrust Shelf Attachment to X _o 1307 Bulkhead	4-11
4-6	Aft Hoist Point	4-13
4-7	Vertical Stabilizer Forward Spar/Fuselage Attach	4-16
4-8	Aft Fuselage Frames	4-18
4-9	Aft Fuselage Lower Skins	4-20
4-10	Wing Aft Spar Fuselage Carry-Through Frame at X _o 1365 and Floor Beam at X _o 1470	4-22
4-11	Upper Thrust Shelf Support Truss Attach	4-24
4-12	Lower Thrust Shelf Support Truss Attach	4-27
4-13	Boron/Epoxy-Thrust Structure Bonds	4-30
4-14	Main Engine Gimbal Actuator Points	4-32
4-15	Main Engine Support and Gimbal Points	4-35
4-16	Lower Thrust Shelf and Main Engine Feedline Support Attachments	4-38
4-17	Upper Thrust Shelf and Main Engine #1 Feedline Support Attachments	4-40
4-18	Canted Frame - Lower Portion	4-42
4-19	Canted Frame - Upper Portion	4-45
4-20	Vertical Thrust Truss Attachments	4-48
4-21	Fin Support Frame, Clevis Attach	4-52
4-22	Base Heat Shield Framing Structure	4-54
4-23	Base Heat Shield Dome Structures	4-57

SECTION 4 - LIST OF FIGURES (continued)

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
4-24	OMS Pod Attach to Aft Fuselage	4-59
4-25	Upper Longeron, OMS Deck	4-61
4-26	OMS Engine Gimbal Actuator Attach	4-63
4-27	OMS Engine Thrust Support Structure	4-66
4-28	Aft RCS Pod Attach Structure	4-69
4-29	Aft RCS Engine Mounts	4-71
4-30	Aft Body Flap Hinges	4-73
4-31	Aft Body Flap Hinge Spar/Rib Attach	4-75
4-32	Aft Body Flap Front Spar	4-77
4-33	Aft Body Flap Honeycomb Skin Panels	4-80

PROCEDURE NO. 4-501, Figure 4-1

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT
(X) PREFLIGHT

SUBASSEMBLY: AFT ET/ORBITER ATTACH

DRAWING(S): VL70-005100, VL70-355026,
VL70-350106 'A'

COMPONENT/AREA DESCRIPTION: AFT ORBITER/ET ATTACH FITTING. This structure is located on the lower side of the Orbiter fuselage at $X_{\circ} 1307$, $Y_{\circ} \pm 96.5$, and is the attachment interface common to the Orbiter and external tank. This fitting, attached to the aft fuselage forward bulkhead and aft fus lower floor, carries reaction loads between these vehicles due to ignition, G-loads, vibrations, gusts and buffeting, aerodynamics, and staging and static loads. The fittings are made of diffusion bonded titanium (6Al-4V) alloy and are attached to aluminum alloy structure. The lower surface of the fuselage in this area is protected by RSI/TPS. Access may be restricted after mating with the ET, but if the mated vehicle is subjected to lengthy periods of heavy ground winds or gusts the interfacial attachments should be inspected prior to liftoff.

DEFECTS: Cracks may develop from fatigue, overstress or adverse conditions around bolt holes in the base of the fitting where attachments are made to aft-fus floor structure, $X_{\circ} 1307$ bulkhead and floor longeron.

ACCESS: For preflight or post flight inspection, enter the aft fuselage lower area through the aft fus access opening to place x-ray film. For backup inspection, remove the fastener at the suspected hole.

NDT TECHNIQUES: Primary: Radiography (para. 1.5.6.2) for the built-up base/floor structure, ultrasonic shear wave (para. 1.5.5.3 B & C) for additional coverage of fitting base around fastener holes.

Backup: Eddy current bolt hole (para. 1.5.4.3).

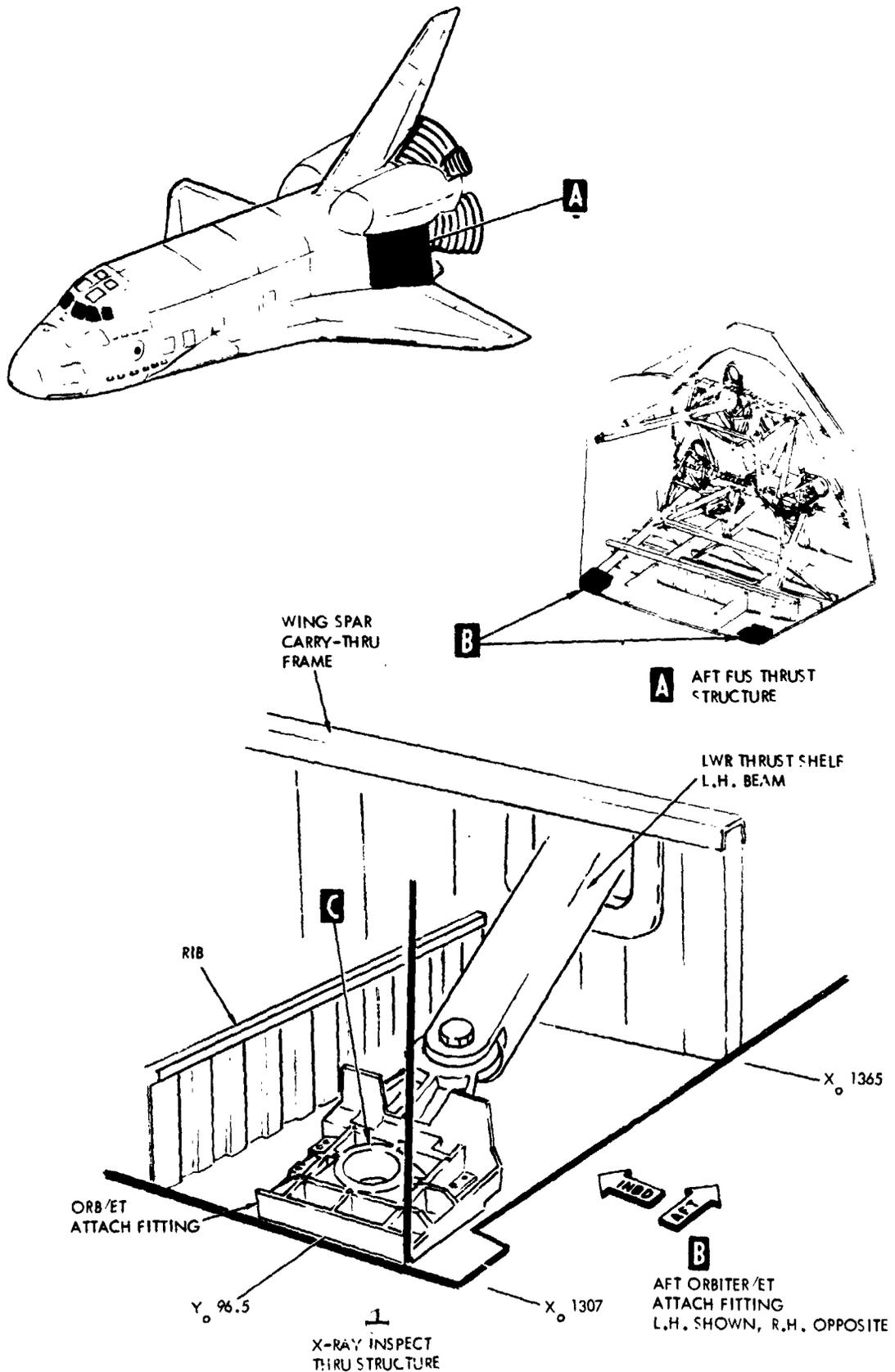


Figure 4-1. Aft ET/Orbiter Attach Fitting (Sheet 1 of 2)

ULTRASONIC INSPECT
AROUND FASTENER HOLES

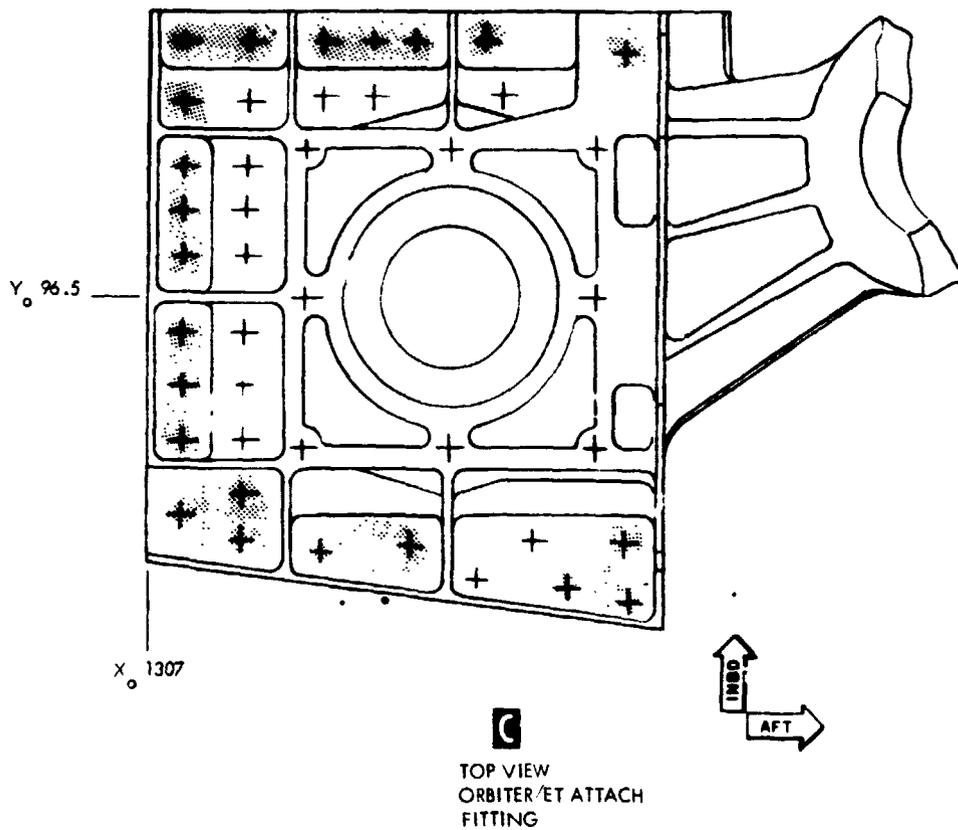


Figure 4-1. Aft ET/Orbiter Attach Fitting (Sheet 2 of 2)

PROCEDURE NO. 4-502, Figure 4-2

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: AFT FUS FWD BULKHEAD

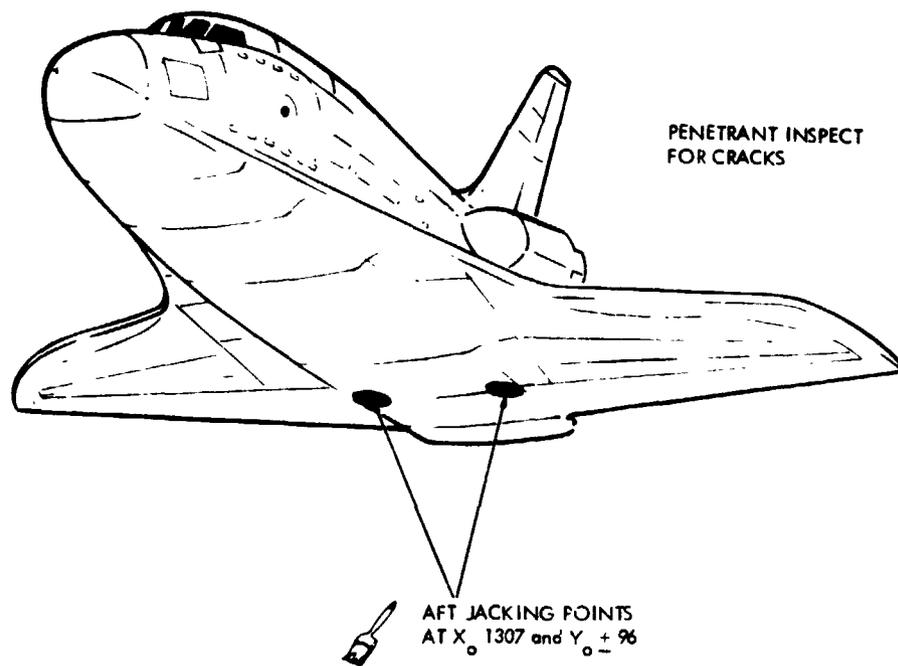
DRAWING(S): VL70-000044 (PRR)

COMPONENT/AREA DESCRIPTION: AFT JACKING POINTS: Two structural hardpoints on the bottom fuselage surface at the X_{\circ} 1307 bulkhead contain jack pad fittings, one each at $Y_{\circ} \pm 96$. These fittings are made of (TBD) and are finished with (finish TBD). The fitting and adjacent structure receive static loads due to the weight of the Orbiter while on jacks. Further, potential brinelling, nicks, and abrasion damage may enhance corrosive attack in a salt-laden atmosphere.

DEFECTS: Cracks may occur in the fitting because of static fatigue or corrosion, and may occur in adjacent airframe structure.

ACCESS: Remove local TPS on the bottom surface of the craft around the jack points as necessary. Access to fitting and ext structure is readily attained. Access to local internal structure at the bulkhead is attained from inside the mid-fuselage crawl space or in the aft-fuselage lower floor.

NDT TECHNIQUES: Primary: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)
Backup: None required



(INSUFFICIENT DESIGN INFORMATION)

Figure 4-2. Aft Jacking Points

PROCEDURE NO. 4-503, Figure 4-3

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE
ZONE 5

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: WING/FUS LOWER ATTACH

DRAWING(S): VL70-005100, VL70-355034

COMPONENT/AREA DESCRIPTION: AFT-FUS/WING SPAR LOWER

ATTACH PADS. Two built-up splice pads exist at the lower edge of the aft fuselage for attachment of the wing aft spar (X_o 1365) and aft (main) spar (X_o 1307) caps. These pads consist of the skin panel, strap and frame cap on the fuselage side and of wing skin panel, cap and splice fitting on the wing side, which are interspliced outboard of the aft fuselage mold line. The components are made of 2024 aluminum alloy and have a zinc chromate primer and Super-corapon 515-700 paint surface finish. Wing flight loads during high-Q boost, entry, atmospheric flight and tail down landing may produce damage in the splice pads. TPS covers exterior lower surface.

DEFECTS: Longitudinal cracks radiating from fastener holes in the splice occurring inboard or outboard of the mid-fuselage mold line.

ACCESS: Access for placing x-ray film or performing backup inspection is from both the aft fuselage lower compartment and the wing box. Enter the aft fuselage through the aft fus access opening or the wing through the wing fus access opening. Place x-ray tube on ground or platform beneath aft fus.

NDT TECHNIQUES: Primary: Radiography (para. 1.5.6.2) for general inspection on either inboard or outboard portions; eddy current surface probe (para. 1.5.4.4) for frame cap or wing splice fitting for special inspections around fasteners.

Backup: Remove suspect fastener and perform eddy current bolt hole inspection (para. 1.5.4.3). Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9) can be used on exposed surfaces after stripping finish.

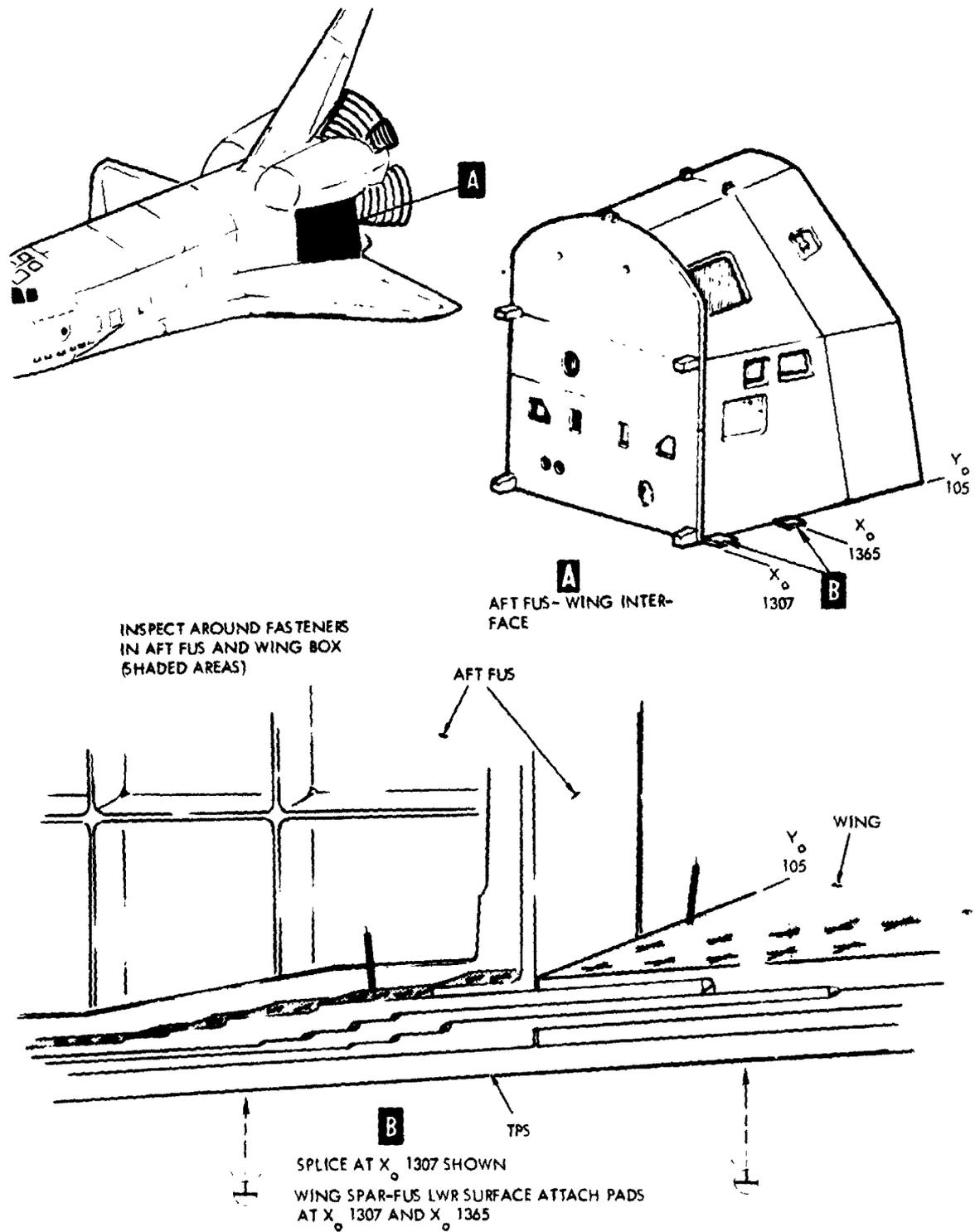


Figure 4-3. Aft-Fuselage/Wing Spar Lower Attach Pads

PROCEDURE NO. 4-504, Figure 4-4

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-005100, VL70-005093, VL70-355016

COMPONENT/AREA DESCRIPTION: LOWER THRUST SHELF ATTACHMENT

TO X_o 1307 AND AFT FUS FLOOR. The lower thrust shelf attaches to a aft-fus fwd bulkhead attachment fitting on each side of the fuselage at X_o 1307, Y_o ± 96.5 and Z_o 267. The attachment fitting mates with the lower shelf fwd extremity at a clevis lug/bolt joint at X_o 1317. Truss members also attach to floor beam at Y_o ± 52.2 and X_o 1380. Thrust loads during liftoff and ascent from main engines 2 and 3 are transferred to the fwd bulkhead and mid-fuselage longerons at these points. The area also receives thrust, inertial, wing and drag loads from the ET/SRB vehicles during ascent. The material of construction is titanium-6Al-4V alloy.

DEFECTS: Cracks in clevis bolt holes and fitting attachment areas at the bulkhead.

ACCESS: Access is gained by entering the aft fus lower area by way of the personnel access openings in the aft fuselage side walls and thrust structure. Also by entering the mid-fus underfloor crawl space. Backup inspection will require disconnecting the shelf arm from the fittings.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for lug bolt-holes, eddy current surface probe (para. 1.5.4.4) for lug/base fillets.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

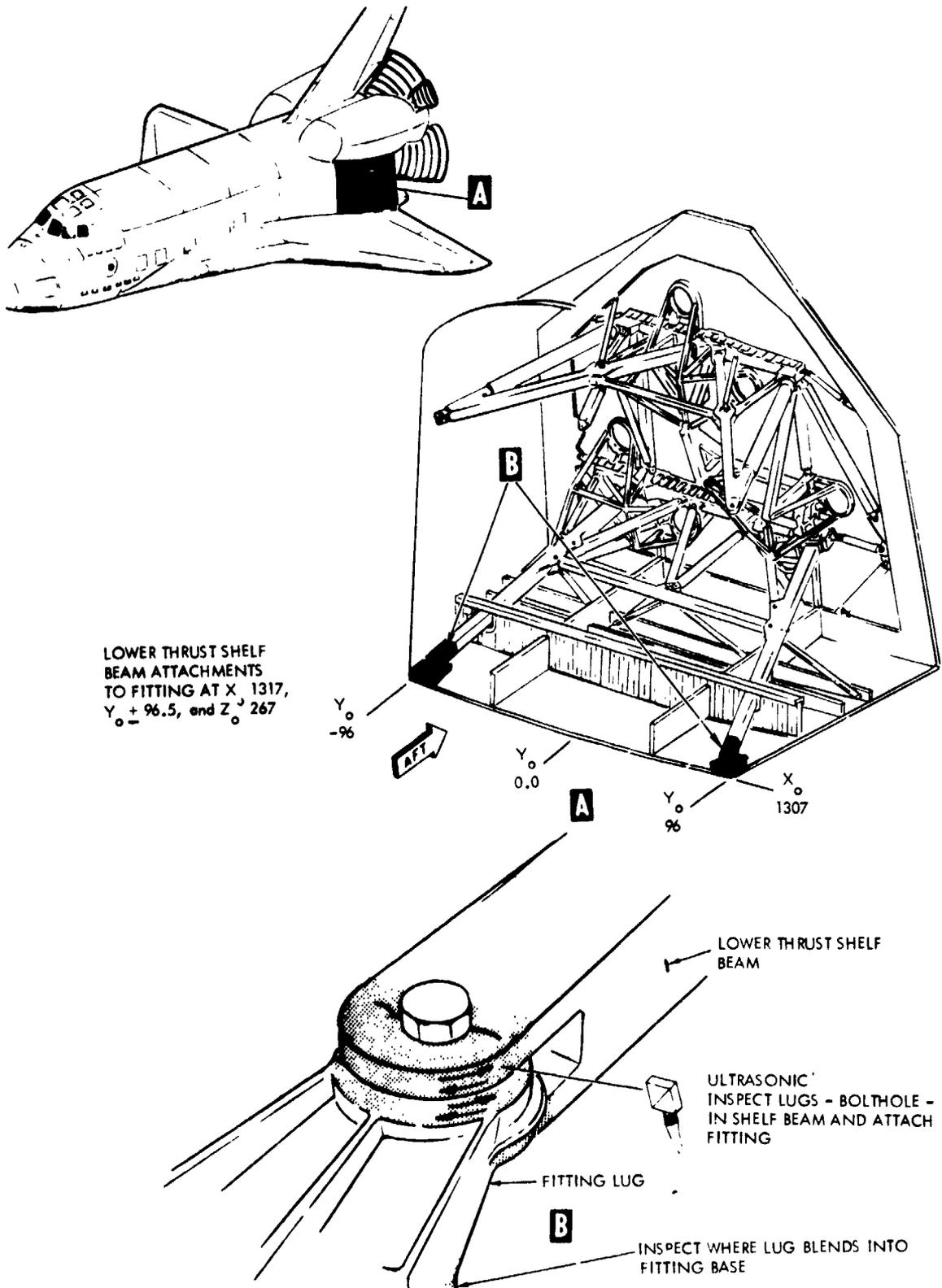


Figure 4-4. Lower Thrust Shelf Attachment to X_o 1307 Bulkhead and Aft Fuselage Floor

PROCEDURE NO. 4-505, Figure 4-5

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-005100, VL70-005093, VL70-355009

COMPONENT/AREA DESCRIPTION: UPPER THRUST SHELF ATTACHMENT

TO X_o 1307 BULKHEAD. The upper thrust shelf attaches to the aft-fus forward bulkhead at an attach fitting on each side of the fuselage at X_o 1312, Y_o ± 96.5 and Z_o 410. Thrust loads during liftoff and ascent from main engine No. 1 are transferred to the fwd bulkhead and fuselage sill longerons at these points. The area also receives fuselage torsional loads and thermomechanical loading during ascent, orbiting, entry, aerodynamic flight and landing. The material of construction is Ti-6Al-4V alloy.

DEFECTS: Cracks in the clevis bolt holes in the shelf arm and attach fitting and fitting attachment areas to fwd bulkhead.

ACCESS: Enter the aft fus compartment by way of the personnel entrance opening in the aft fus side wall. Also, access to the fwd side of the X_o 1307 bulkhead is attained from the payload bay.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) and eddy current (para. 1.5.4.4) for fillets.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

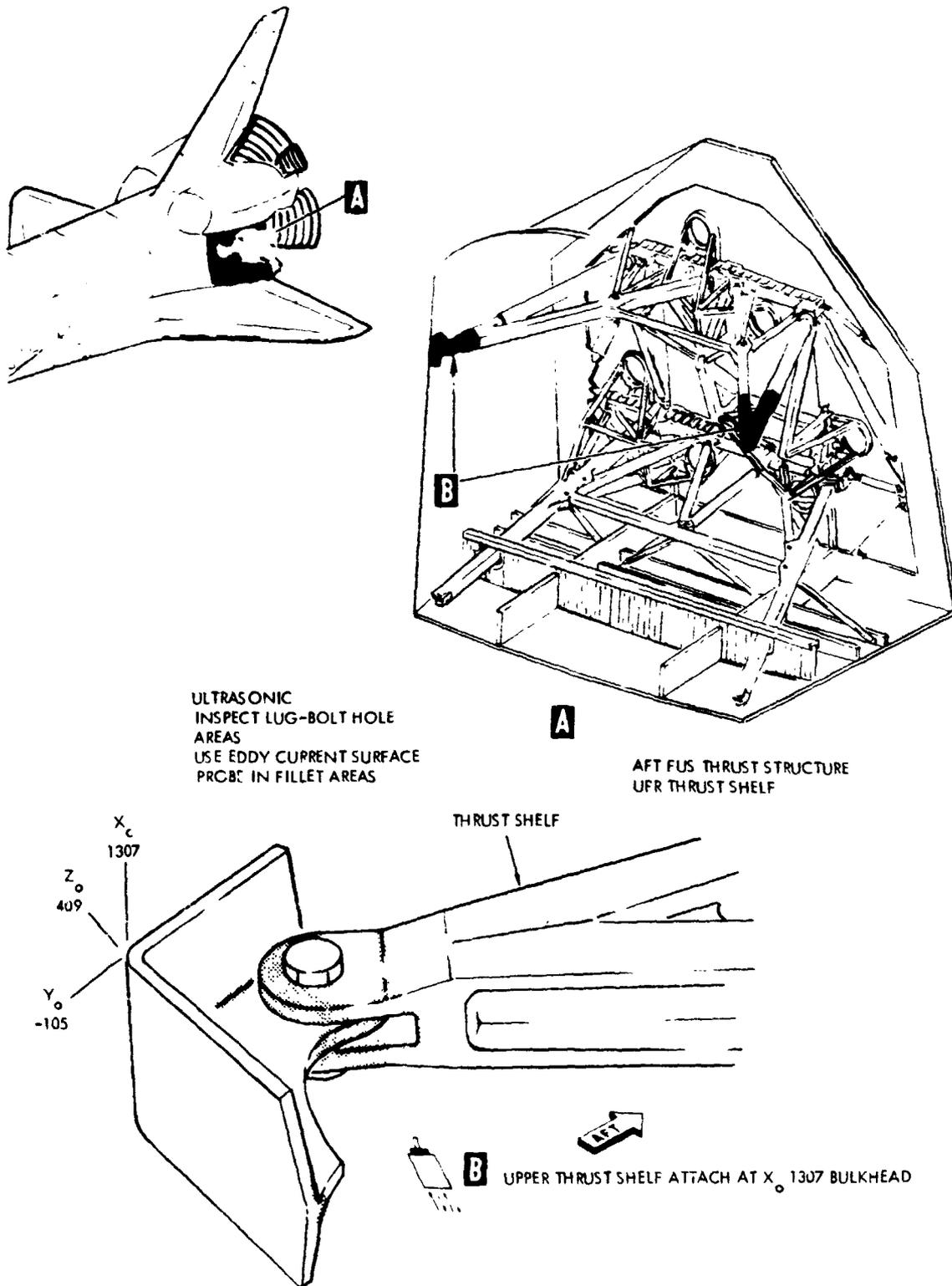


Figure 4-5. Upper Thrust Shelf Attachment to X_c 1307 Bulkhead

PROCEDURE NO. 4-506, Figure 4-6

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: AFT FUS FWD BULKHEAD

DRAWING(S): VL70-005100, VL70-355028

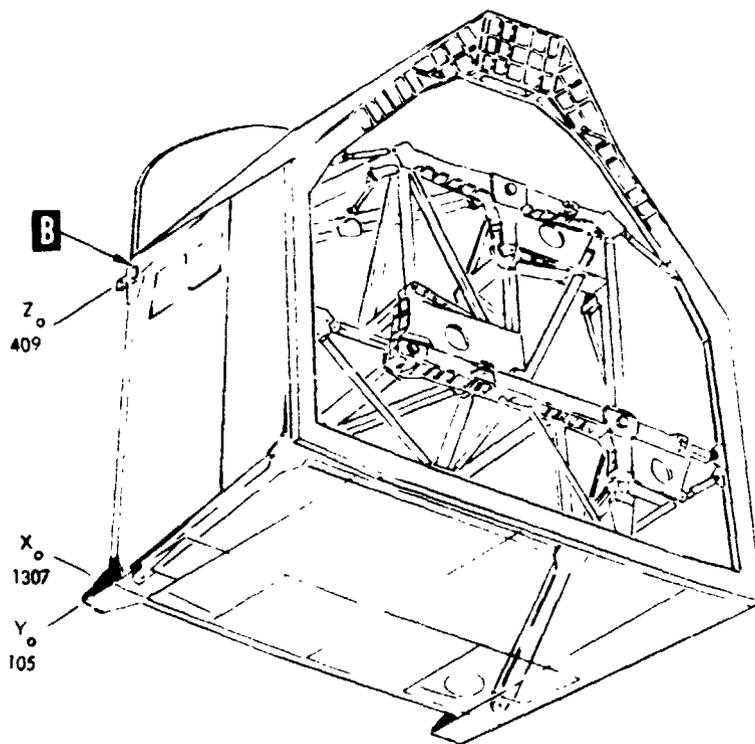
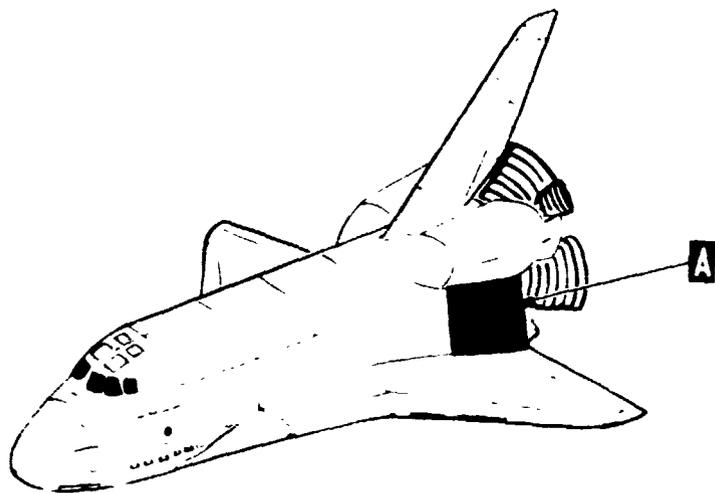
COMPONENT/AREA DESCRIPTION: AFT HOIST POINT. The aft hoist fitting is located at $X_{\circ} 1307$, $Z_{\circ} 408$ and $Y_{\circ} \pm 105$ and is machined from diffusion bonded titanium (6A1-4V) alloy. The fitting also interfaces with the upper thrust shelf forward attach and the mid-fus sill longeron. The fitting not only receives some of the main engine thrust and flight loads, but supports much of the weight of the vehicle during hoisting operations and during launch preparation when the mated Shuttle vehicles are on the launch pad.

DEFECTS: Cracks may occur around fitting-to-sill longeron splice bolt holes; in fitting attachment holes to $X_{\circ} 1307$ bulkhead and aft-fus side frame; in fillets where bearing housing blends into side flanges.

ACCESS: The inspection areas are accessible from the cargo bay (mid-fus), the aft-fus compartment upper level and from outside fuselage. RSI/TPS materials cover the exterior fuselage surface in the local area.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3) for bolt holes at fitting to aft fus longeron splice; eddy current for accessible areas; radiography (para. 1.5.6.2) at flange-to-side frame of flange-to- $X_{\circ} 1307$ bulkhead attachment.

Backup: Eddy current bolt hole (para. 1.5.4.3)



A

AFT FUS HOIST POINT

Figure 4-6. Aft Hoist Point (Sheet 1 of 2)

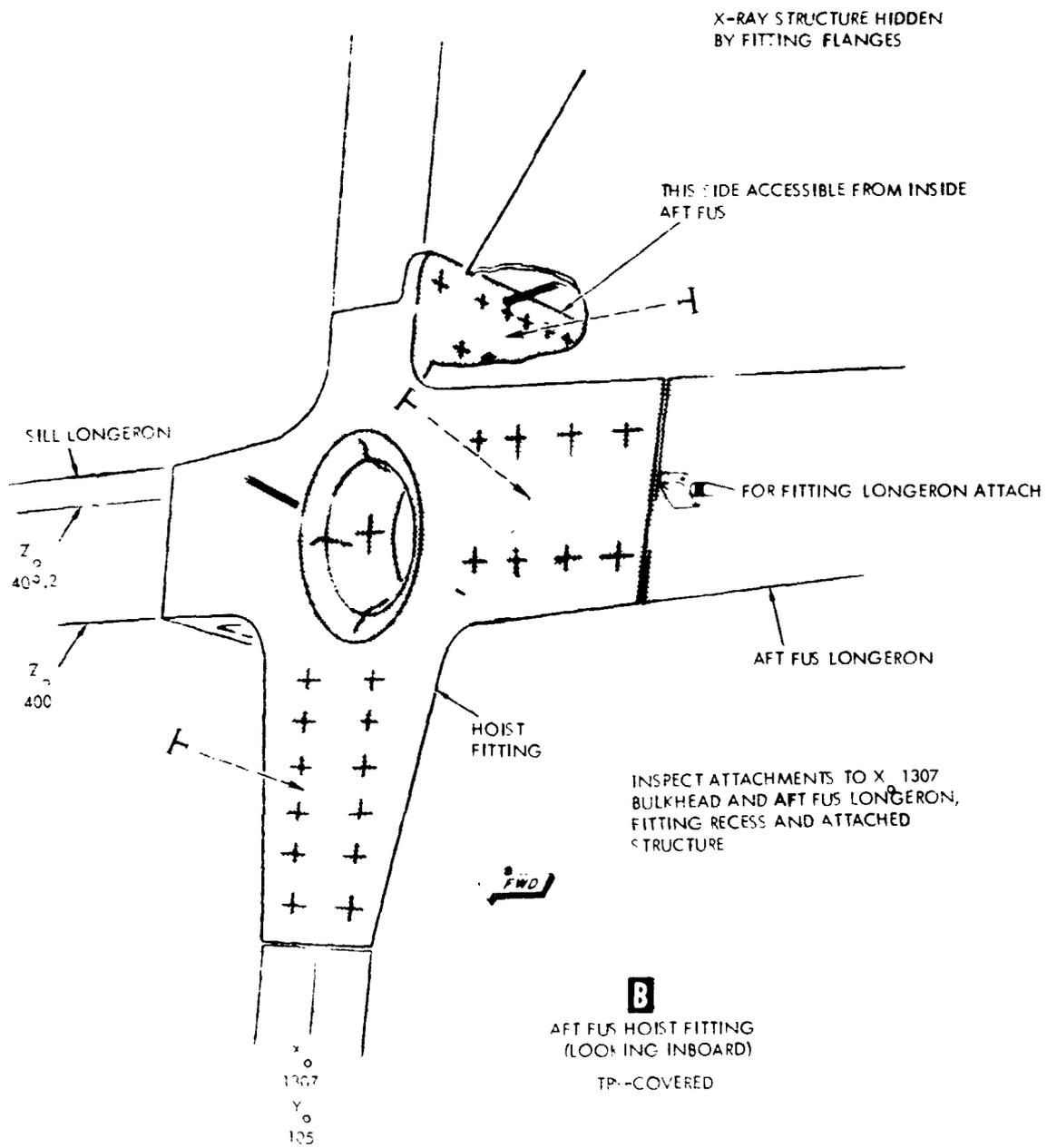


Figure 4-6. Aft Hoist Point (Sheet 2 of 2)

PROCEDURE NO. 4-507, Figure 4-7

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: AFT FUS/VERT STAB INTERFACE

DRAWING(S): VL70-005107, VL70-355023

COMPONENT/AREA DESCRIPTION. VERTICAL STABILIZER FORWARD

SPAR-TO-FUSELAGE ATTACH. The vertical stabilizer forward spar is attached to the fuselage at $X_{\circ} 1309$, $Z_{\circ} 503$ and $Y_{\circ} \pm 4$. The fwd spar, aft fus fwd bulkhead, and the aft fus vertical stabilizer support shelf have a common attach fitting at this point. The fitting is attached to the vert stab support shelf by two large-diameter bolts and a flanged base. A vertical flange attaches to the $X_{\circ} 1307$ bulkhead aft side and a aft-canted flange attaches to the vert stab forward spar. The fitting reacts fin loads due to wind shear, G-force, dynamic pressure and vibroacoustics and may develop fatigue damage.

DEFECTS: Cracks at the two large-diameter bolt holes or at fastener holes at the vertical, horizontal or canted flanges. Cracks may also occur in the fillets where the flanges blend into the base or body of the fitting.

ACCESS: Access to the vertical flange of the fitting is gained from the aft fus compartment upper level; the upper flanges and body of the fitting are inspected by removing the access fairing at the base of the vert stab leading edge.

NDT TECHNIQUES: Primary: Radiography (para. 1.5.6.2) for flange inspection, eddy current surface probe (para. 1.5.4.4) for fillet areas; ultrasonic shear wave (para. 1.5.5.3 C) for bolt holes.

Backup: Eddy current bolt hole (para. 1.5.4.3) and fluorescent penetrant (para. 1.5.2.1 Fig 1-9).

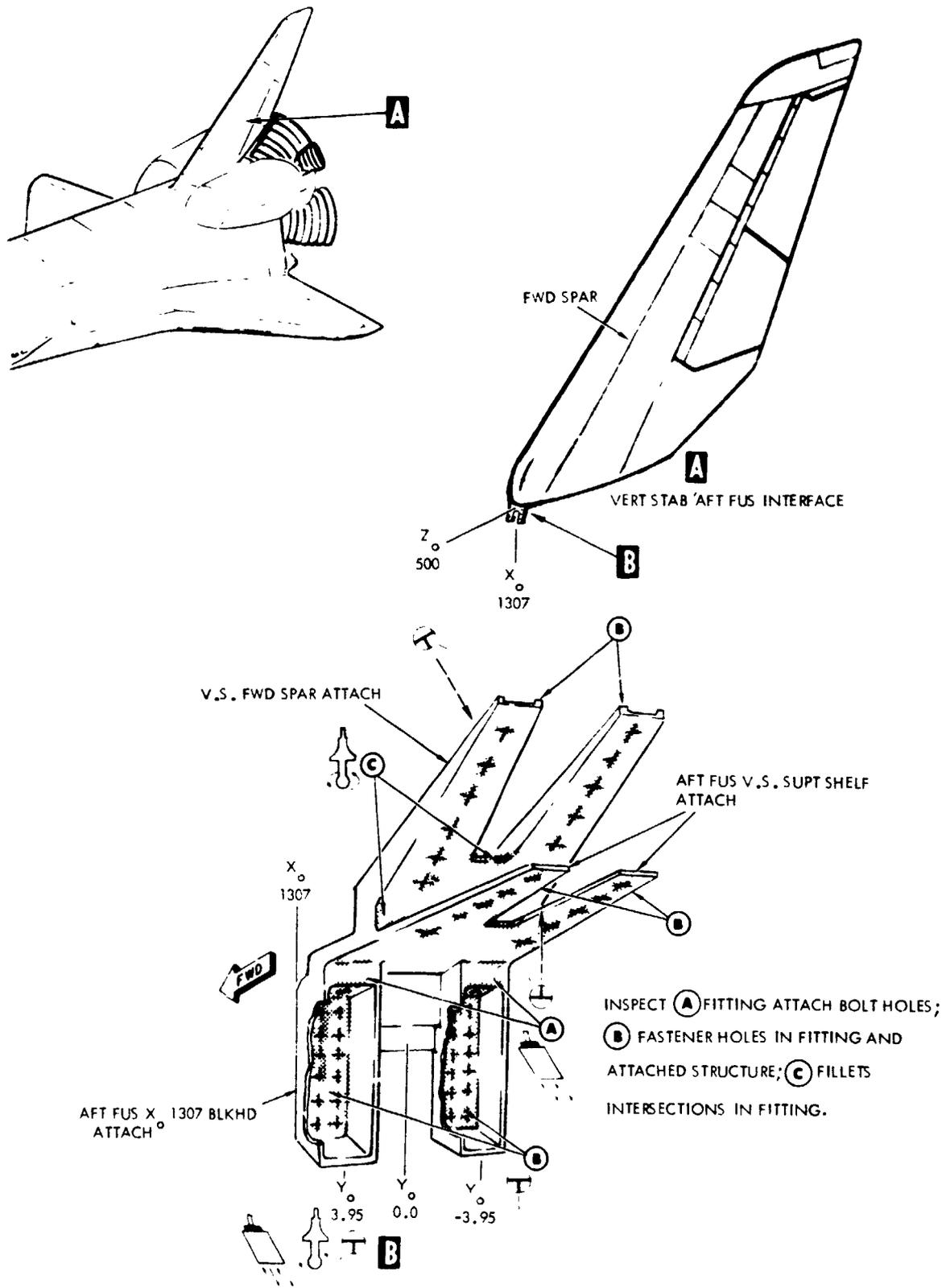


Figure 4-7. Vertical Stabilizer Forward Spar/Fuselage Attach

PROCEDURE NO. 4-508, Figure 4-8

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUB ASSEMBLY: AFT FUS SHELL

DRAWING(S): VL70-005100, VL70-355036, VL70-355064

COMPONENT/AREA DESCRIPTION: AFT FUSELAGE FRAMES. The aft fuselage frames are built-up structures consisting of inner and outer caps, webs, and reinforcement structures and are made either of 2024-T851 or 2024-T4 aluminum alloy. The frames receive secondary main engine and OMS thrust loads and wind gust loads acting on the vertical fin. An engine-out condition can create adverse load conditions in the aft fuselage structure. The frames should be inspected along the inner caps splice fittings and web attachments, at the splices at the $Z_{\circ} 415$ and $Z_{\circ} 488$ water planes and at $Y_{\circ} \pm 20$ and $Y_{\circ} \pm 105$, respectively. Typical frames are at stations $X_{\circ} 1324$, $X_{\circ} 1340$, $X_{\circ} 1360$ and $X_{\circ} 1400$. The frames have a zinc chromate primer and Supercorapon 515-700 paint surface finish.

DEFECTS: Horizontal cracks radiating from fastener hole in the vicinity of frame splices, in the frame caps, splice fittings, cap-to-web joints.

ACCESS: Access to the fittings is attained from inside the aft fus compartment, upper level, which is reached by entering the aft fus access opening.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4), radiography (para. 1.5.6.2) for "buried" frame or splice members.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).

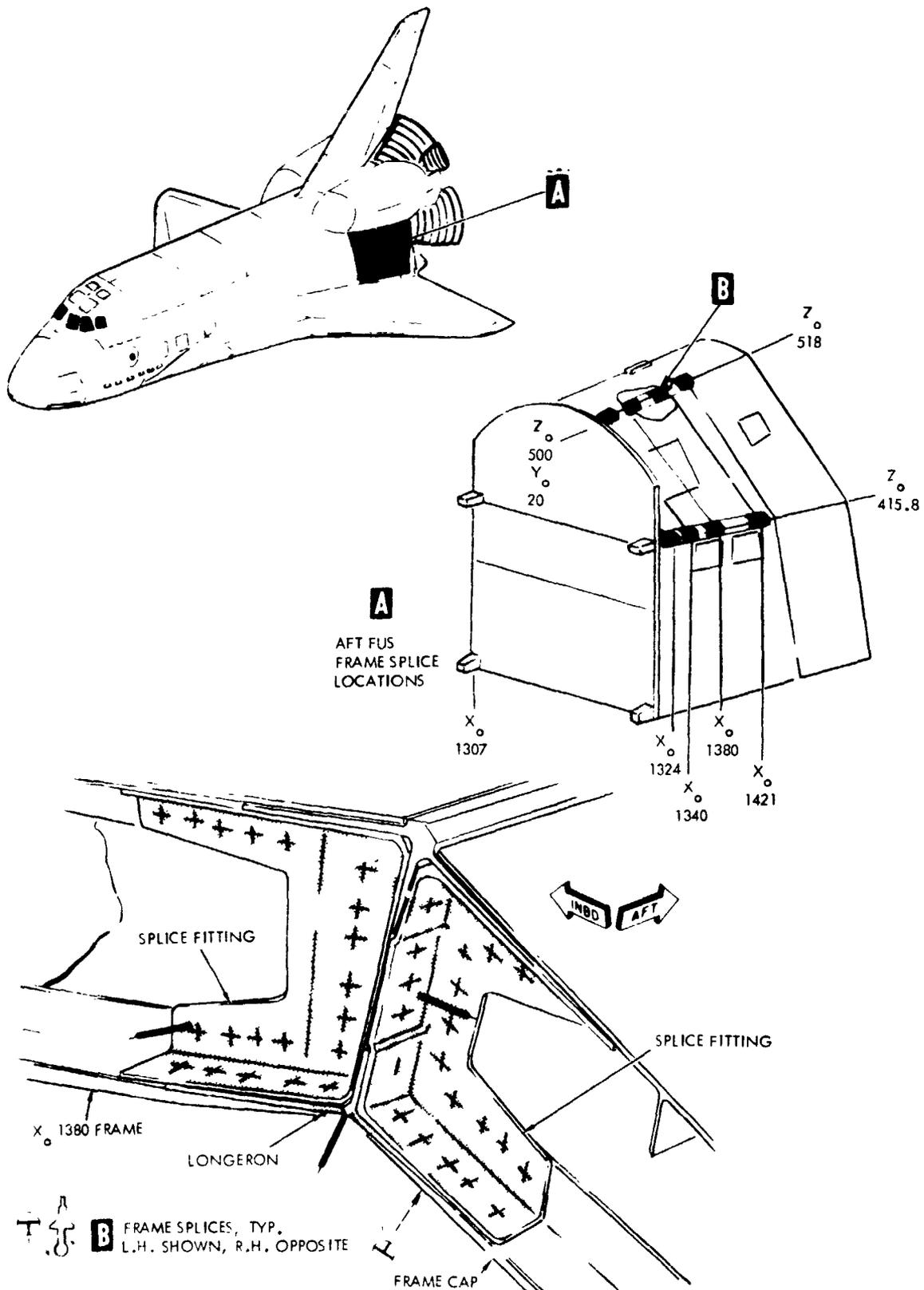


Figure 4-8. Aft Fuselage Frames

PROCEDURE NO. 4-509, Figure 4-9

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE
ZONE 5

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: AFT FUS SHELL

DRAWING(S): VL70-005100, VL70-355055

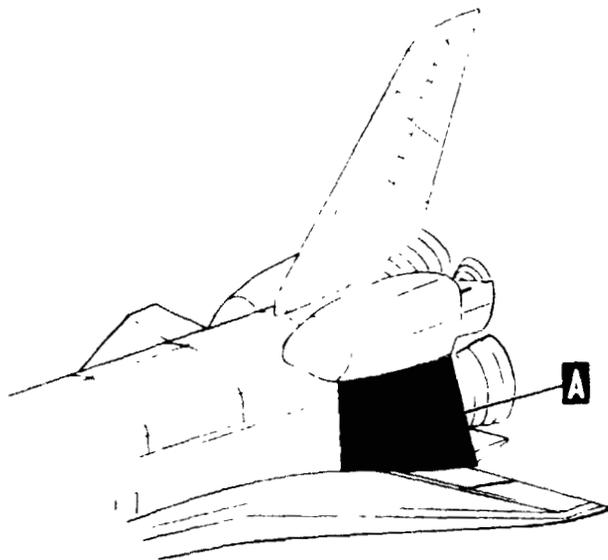
COMPONENT/AREA DESCRIPTION: AFT FUSELAGE LOWER SKINS. These skins are integrally stiffened with T-section stringers and are machined from 2124-T851 aluminum alloy plate and have a zinc chromate primer and Super-corapon 515-700 paint surface finish. The outer surface of the skin is protected by LRSI/TPS panels. Load reactions at particular locations may induce fatigue damage in skin fastener holes in these locations.

DEFECTS: Skin cracks emanating from fastener holes or skin panel edges.

ACCESS: Access to the areas is from inside and outside the aft fuselage compartment lower area and the main wing box. Enter the aft fuselage through the aft fus access opening and the wing box through the fuselage-to-wing access opening. Back-up inspection may require removal of local TPS panels.

NDT TECHNIQUES: Primary: Radiography (para. 1.5.6.2) for all areas outside of wing box area, eddy current surface probe (para. 1.5.4.4) for areas inside wing box (not covered by TPS).

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



RADIOGRAPHIC INSPECT
SKIN SPLICE AREAS.

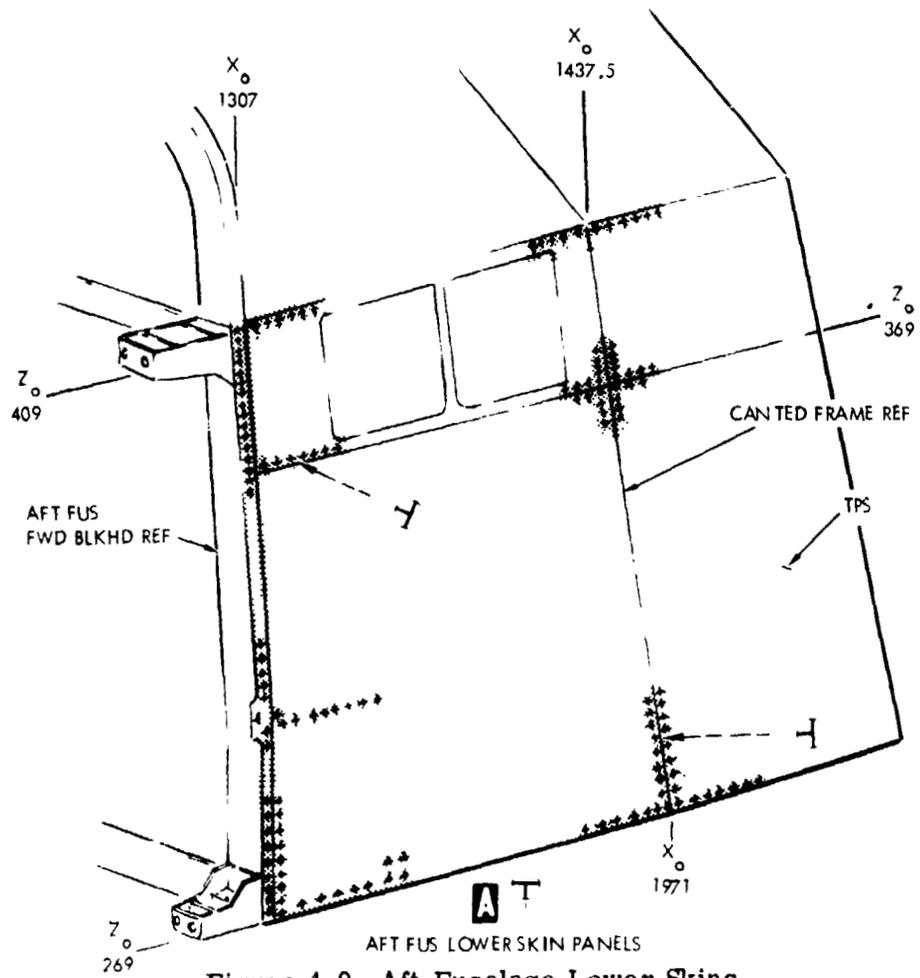


Figure 4-9. Aft Fuselage Lower Skins

PROCEDURE NO. 4-510, Figure 4-10

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: AFT FUS CARRY-THROUGH FRAME

DRAWING(S): VL70-005100, VL70-355034, VL70-355038,
VL70-354111, VL70-355302

COMPONENT/AREA DESCRIPTION: WING AFT SPAR FUSELAGE CARRY-
THROUGH FRAME AT X_o 1365 AND FLOOR BEAM AT X_o 1470.

The wing aft spar fuselage carry-through frame, made from 2024-T8511 aluminum alloy extrusions, may experience fatigue damage on the upper and lower caps near the aft-fus sides because of wing flexure, and ET/Orb interaction loads.

The floor beam at X_o 1470 of similar materials experiences loads from the thrust structure truss attachments at Y_o ± 52.5 and from the tail fin support frames at Y_o ± 122. The upper and lower caps on these frames and the lug bolt holes at the thrust truss attachments should be inspected.

DEFECTS: Radial cracks at fastener holes and edge cracks in frame caps in inspection areas of both frames. Radial cracks in lug bolt holes in the thrust truss attach fitting and attachments of this fitting to the X_o 1470 beam.

ACCESS: Enter the aft fuselage compartment lower area through the aft fus access opening. Backup inspection may involve removal of fastener or bolt in suspect bolt-hole.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4) for upper cap and fillet areas radiography (para. 1.5.6.2) for bottom caps on X_o 1365 spar near wing aft spar attach area (radiograph spar cap, doubler and skin); ultrasonic longitudinal wave (para. 1.5.5.3 A) for X_o 1365 frame upper cap attach to wing aft spar.

Backup: Eddy current bolt hole (para. 1.5.4.3)

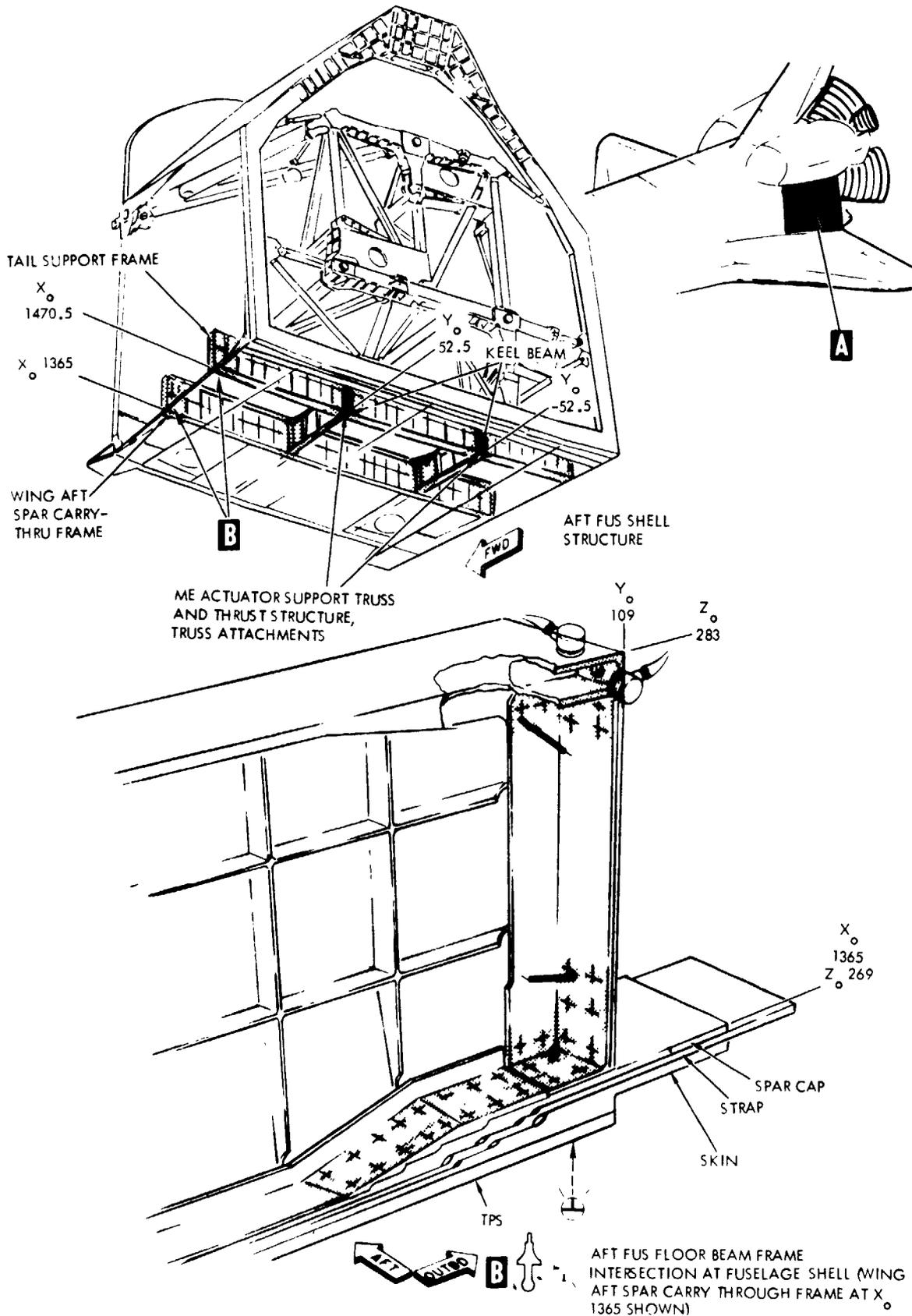


Figure 4-10. Wing Aft Spar Fuselage Carry-Through Frame at X_0 1365 and Floor Beam at X_0 1470

PROCEDURE NO. 4-511, Figure 4-11

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION:
(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-005100, VL70-355009

COMPONENT/AREA DESCRIPTION: UPPER THRUST SHELF SUPPORT

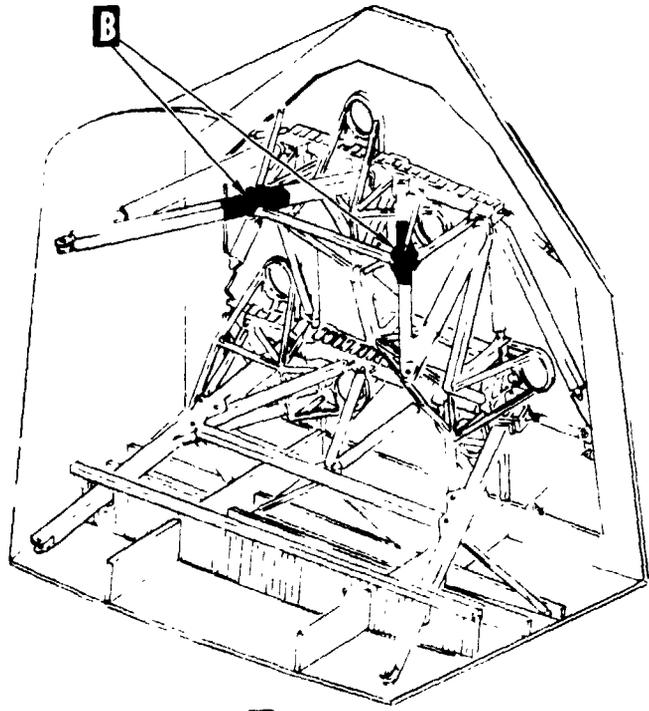
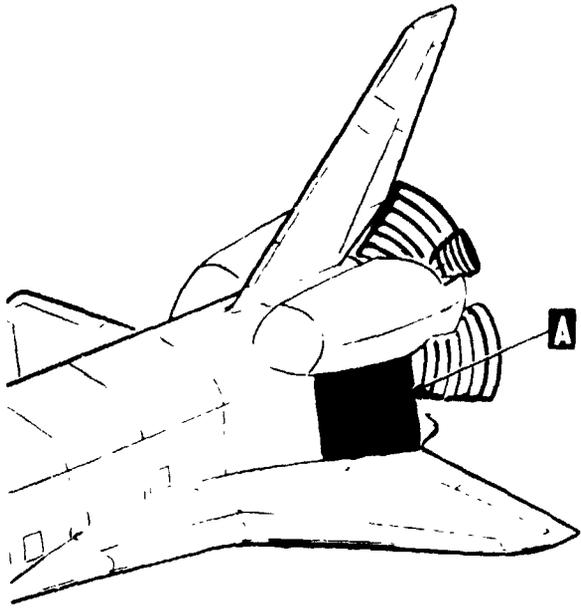
TRUSS ATTACH. The upper thrust shelf principal members are stabilized by titanium (6A1-4V) alloy trusses attached to them at X_o 1377.5, Z_o 430, and $Y_o \pm 44$. Engine thrust and vibroacoustic loads could eventually cause fatigue damage in the clevis bolt holes or the lug-to-base transitions.

DEFECTS: Radial cracks at clevis bolt holes and part-through cracks at lug-base fillets.

ACCESS: Enter the aft fuselage, upper area, through the aft fus access opening. For backup inspection, the suspected truss member may have to be disconnected from the shelf.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for clevis bolt holes, eddy current (para. 1.5.4.4) for fillets and edges of attach fittings.

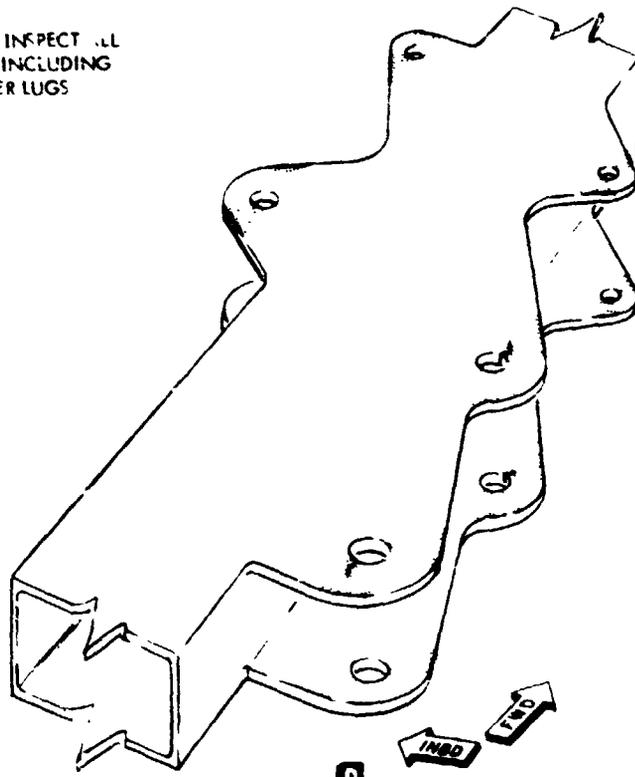
Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



A
UPPER THRUST SHELF
TRUSS ATTACH FITTINGS
X 1380

Figure 4-11. Upper Thrust Shelf Support Truss Attach (Sheet 1 of 2)

ULTRASONIC INSPECT ALL
LUG AREAS, INCLUDING
TRUSS MEMBER LUGS



B
TRUSS ATTACHMENT
(ALTERNATE DESIGN)

Figure 4-11. Upper Thrust Shelf Support Truss Attach (Sheet 2 of 2)

PROCEDURE NO. 4-512, Figure 4-12

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-00510), VL70-355016

COMPONENT/AREA DESCRIPTION: LOWER THRUST SHELF SUPPORT

TRUSS ATTACH. The lower thrust shelf principal members are stabilized by titanium (6Al-4V) alloy trusses attached to them at X_o 1394, X_o 308 and Y_o 0.0 and $Y_o \pm 74$. Engine thrust loads and vibroacoustic loads or engine-out condition could eventually cause fatigue damage in the clevis bolt holes or the lug-to-truss transitions.

DEFECTS: Radial cracks at clevis bolt holes and part-through cracks at lug-base fillets.

ACCESS: Enter the aft fuselage, lower area, through the aft fus access opening. For backup inspection, the suspected truss member may have to be disconnected from shelf.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for clevis bolt holes, eddy current (para. 1.5.4.4) for fillets and edges.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

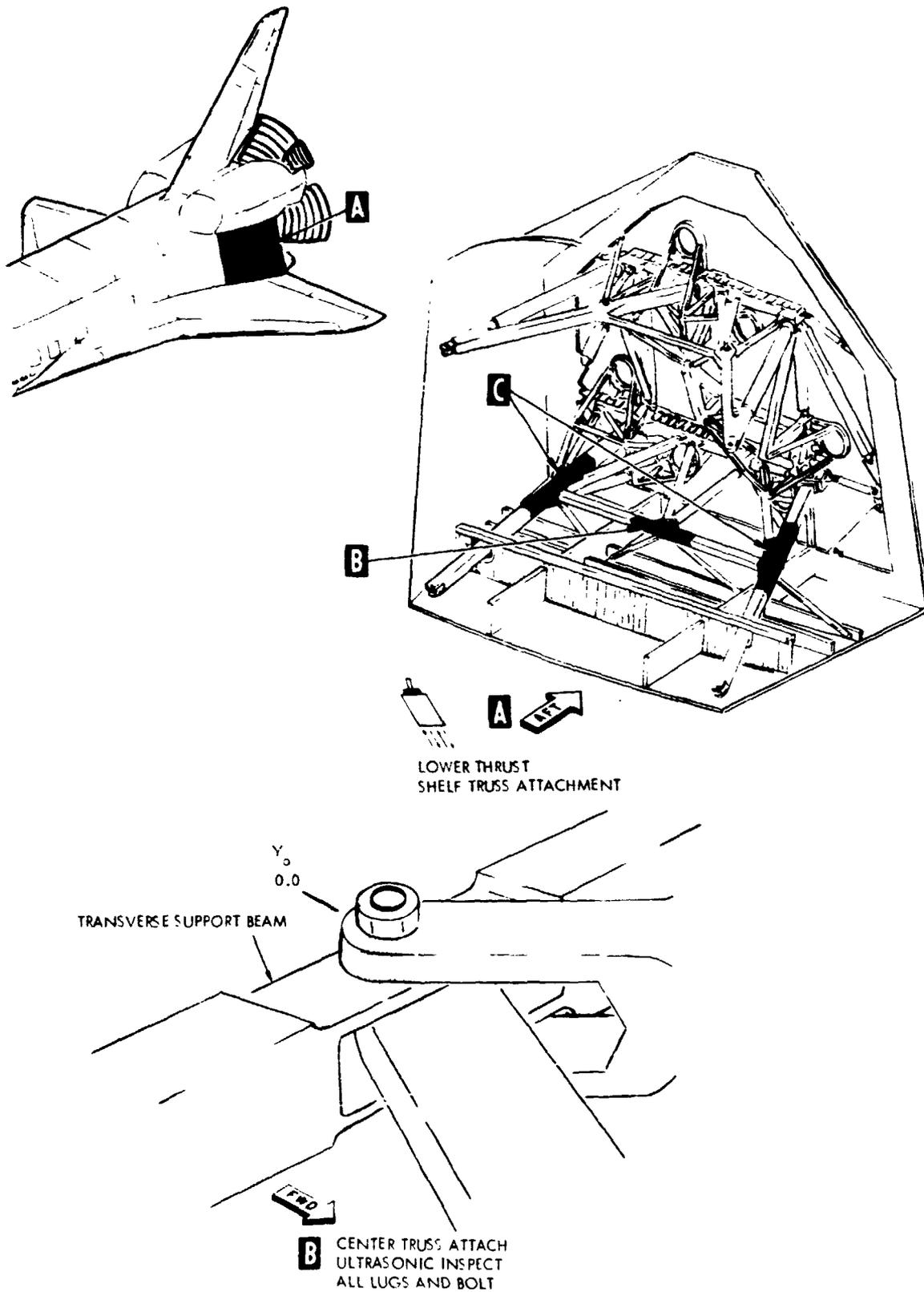
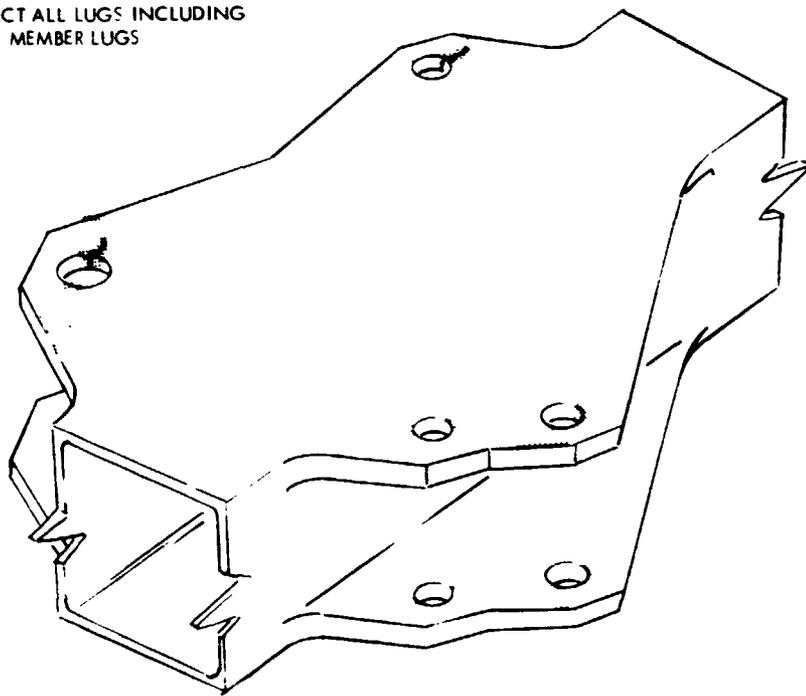


Figure 4-12. Lower Thrust Shelf Support Truss Attach (Sheet 1 of 2)

DIFFUSION BONDED TRUSS
ATTACHMENT
INSPECT ALL LUGS INCLUDING
TRUSS MEMBER LUGS



SIDE (LONGITUDINAL) BEAM
TRUSS ATTACHMENTS
R.H. SHOWN, L.H. OPPOSITE

Figure 4-12. Lower Thrust Shelf Support Truss Attach (Sheet 2 of 2)

PROCEDURE NO. 4-513, Figure 4-13

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: THRUST TRUSSES

DRAWING(S): VL70-000093

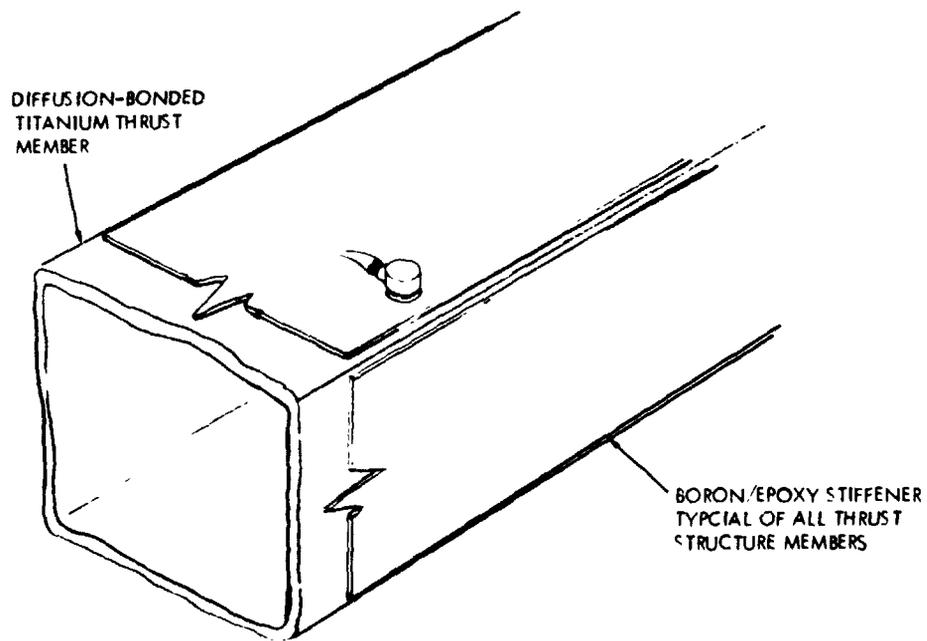
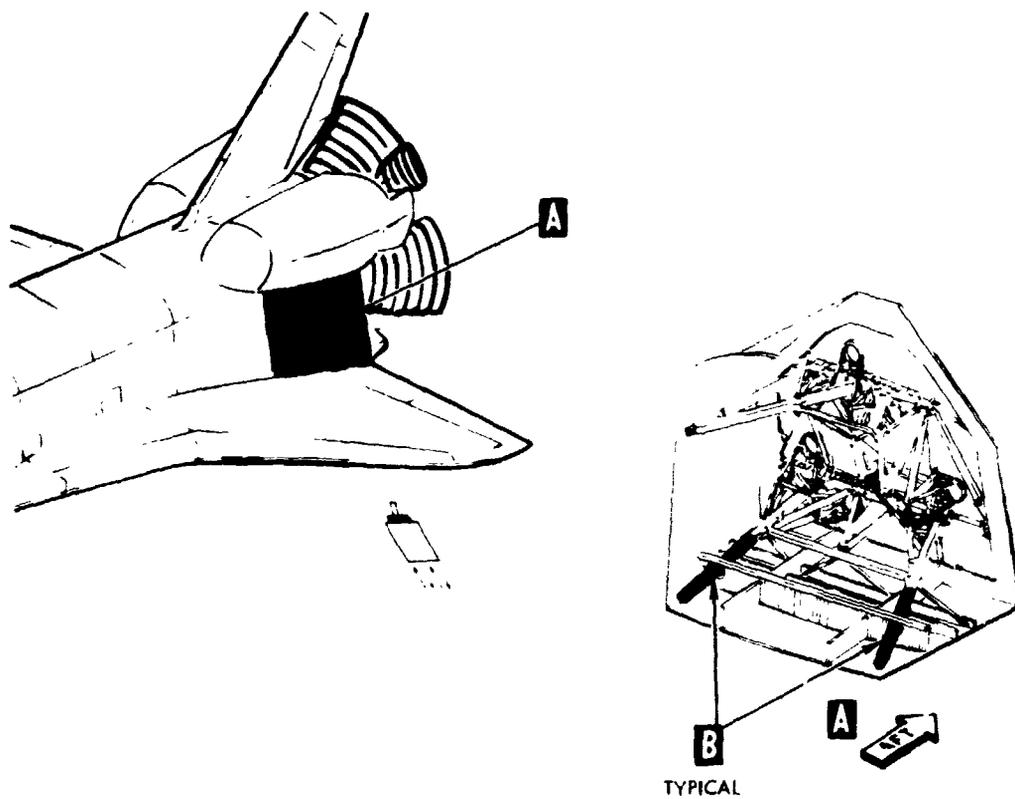
COMPONENT/AREA DESCRIPTION: BORON EPOXY/THRUST STRUCTURE BGNDS.

The main engine thrust members are constructed of round and/or square, diffusion-bonded, titanium tubes which contain bonded boron/epoxy stiffeners bonded to the exterior surfaces of the thrust members. Engine compressive thrust loads and high vibroacoustic loads may tend to cause the stiffeners to become disbonded from the tubular thrust members. All thrust structure members containing B/E stiffeners are affected.

DEFECTS: Disbonds at the boron/epoxy to tubular thrust member interface .

ACCESS: One-sided access only from exterior surface. Components are located in the aft fus compartment, which is entered by way of the aft fus access opening.

NDT TECHNIQUES: Primary: Ultrasonic pulse-echo resonance (para. 1.5.5.6)
Backup: Mechanical pull test if disbond area is larger than TBD inches dia.



B ULTRASONIC INSPECT FOR DIS BONDS BETWEEN STIFFENER AND THRUST MEMBER

Figure 4-13. Boron/Epoxy-Thrust Structure Bonds

PROCEDURE NO. 4-514, Figure 4-14

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-005093, VL70-355009, VL70-355016

COMPONENT/AREA DESCRIPTION: MAIN ENGINE GIMBAL ACTUATOR

POINTS. Each of the three main engines has two gimbal actuator support points located at: 1) main engine No. 1: X_o 1432, Y_o 31 (yaw) and 0.0 (pitch), Z_o 439 (yaw) and 408 (pitch); 2) main engine number 2: X_o 1462, Y_o -21.4 (yaw) and -52.2 (pitch), Z_o 342 (yaw) and 372.9 (pitch); 3) main engine number 3: X_o 1462, Y_o +83.6 (yaw) and +52.2 (pitch), Z_o 342 (yaw) and 311 (pitch). The actuator attachment lug is an integral part of its support frame, machined from annealed diffusion bonded titanium-6Al-4V. The attachment transfers the engine actuator loads to the support frame and experiences ignition vibroacoustic loads.

DEFECTS: Cracks around the lug bolt hole or in the fillet where the lug blends into the base of the attachments. Also similar areas on the truss support on the fwd side of the support beams.

ACCESS: Enter the aft fuselage compartment through the aft fus personnel access opening. Necessity to disconnect actuator TBD except for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3B) and eddy current (para. 1.5.4.4)

Backup: Eddy current bolt hole (para. 1.5.4.3) for lug bolt holes, fluorescent penetrant for other areas (para. 1.5.2.1 Fig. 1-9).

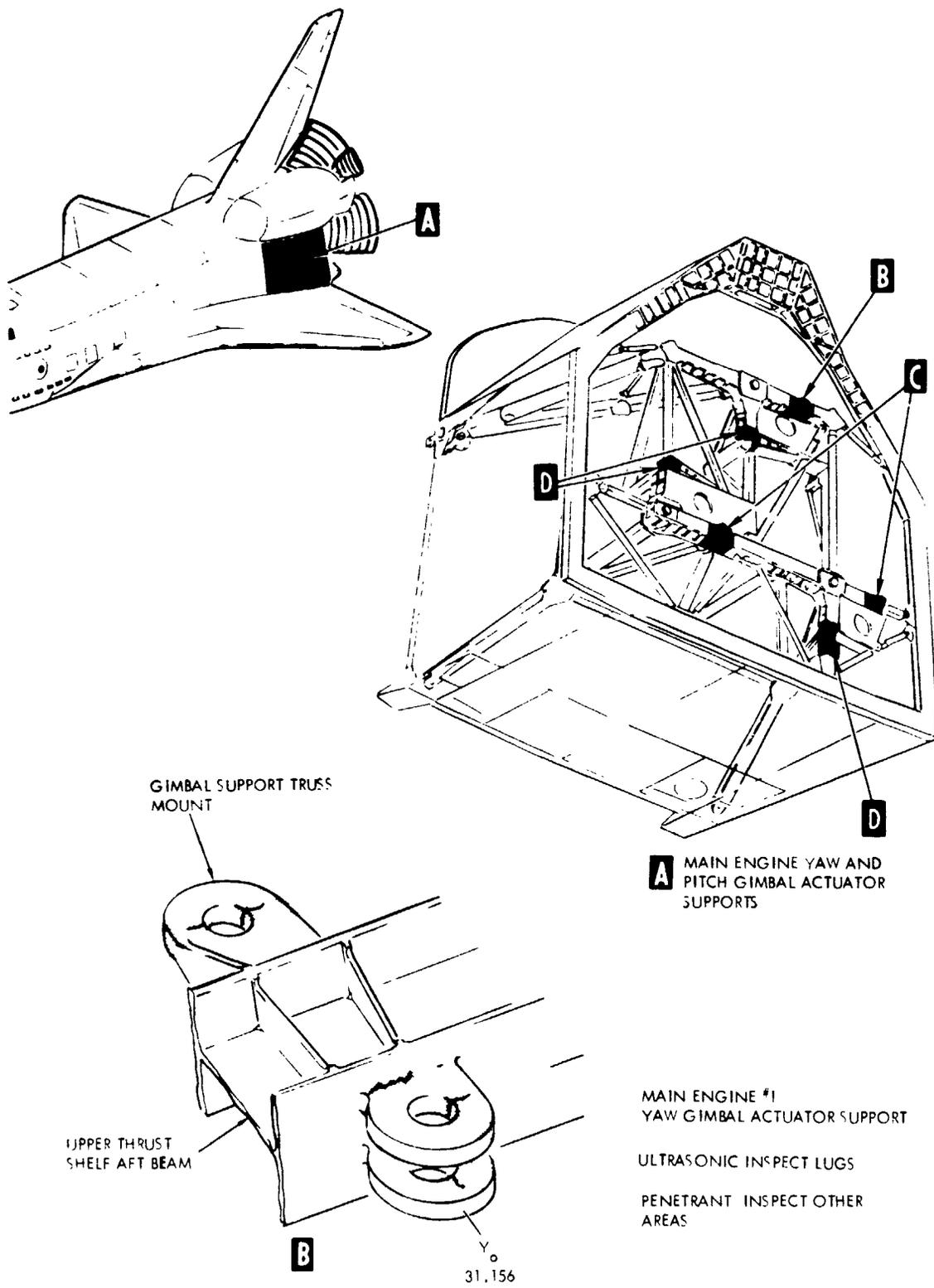
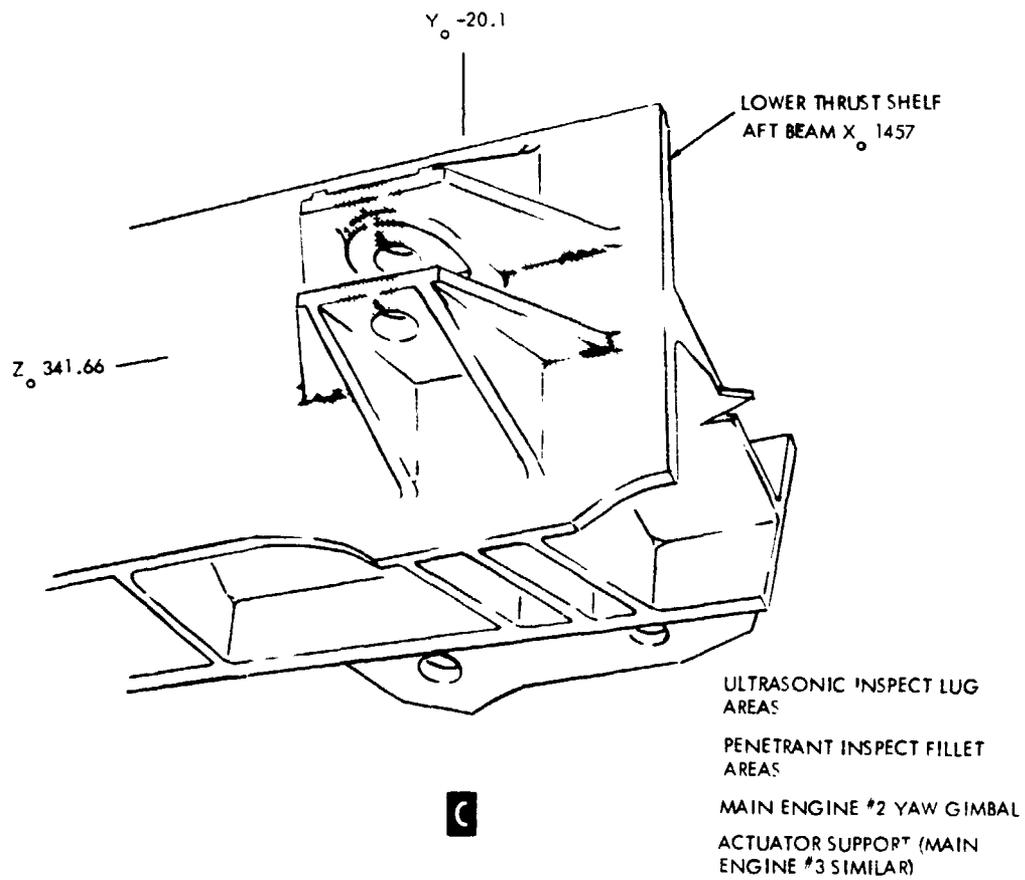


Figure 4-14. Main Engine Gimbal Actuator Points (Sheet 1 of 2)



D

MAIN ENGINE PITCH GIMBAL ACTUATOR SUPPORTS OF SIMILAR NATURE

Figure 4-14. Main Engine Gimbal Actuator Points (Sheet 2 of 2)

PROCEDURE NO. 4-515, Figure 4-15

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-005093, VL70-355009, VL70-355016

COMPONENT/AREA DESCRIPTION: MAIN ENGINE (ME) SUPPORT AND GIMBAL POINTS. The main engine gibal and support structure is located, for Main Engine #1, along the aft edge of the upper thrust shelf and, for Main Engine 2 and 3, along the aft edge of the lower thrust shelf. The titanium-6Al-4V gibal supports are located at: 1) ME #1: X_o 1432, Y_o 0.0, and Z_o 439.3; 2) ME #2: X_o 1458, Y_o -52.4, and Z_o 341; 3) ME #3: X_o 1458, Y_o +52.4, and Z_o 341. The gibal points support the engine, provide the engine pivot point, and receives the direct engine thrust loads. They may be further affected by ignition and lift-off vibro-acoustic loads.

DEFECTS: Cracks in the gibal mechanism and in the thrust beam caps and transverse webs in the area defined by a distance of about 30 inches right and left of the engine gibal point.

ACCESS: Gain access by entering the aft fuselage compartment, upper and lower areas, through the aft-fus access door or the base heat shield aft access opening.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4) for web, cap and fillet areas; ultrasonic shear and/or longitudinal (para. 1.5.5.3) for concealed areas.

Backup: Fluorescent penetrant (para 1.5.2.1 Fig. 1-9)

NOTE: It stripping of surface finished is not required, the eddy current and penetrant inspections for primary and backup can be reversed if desired.

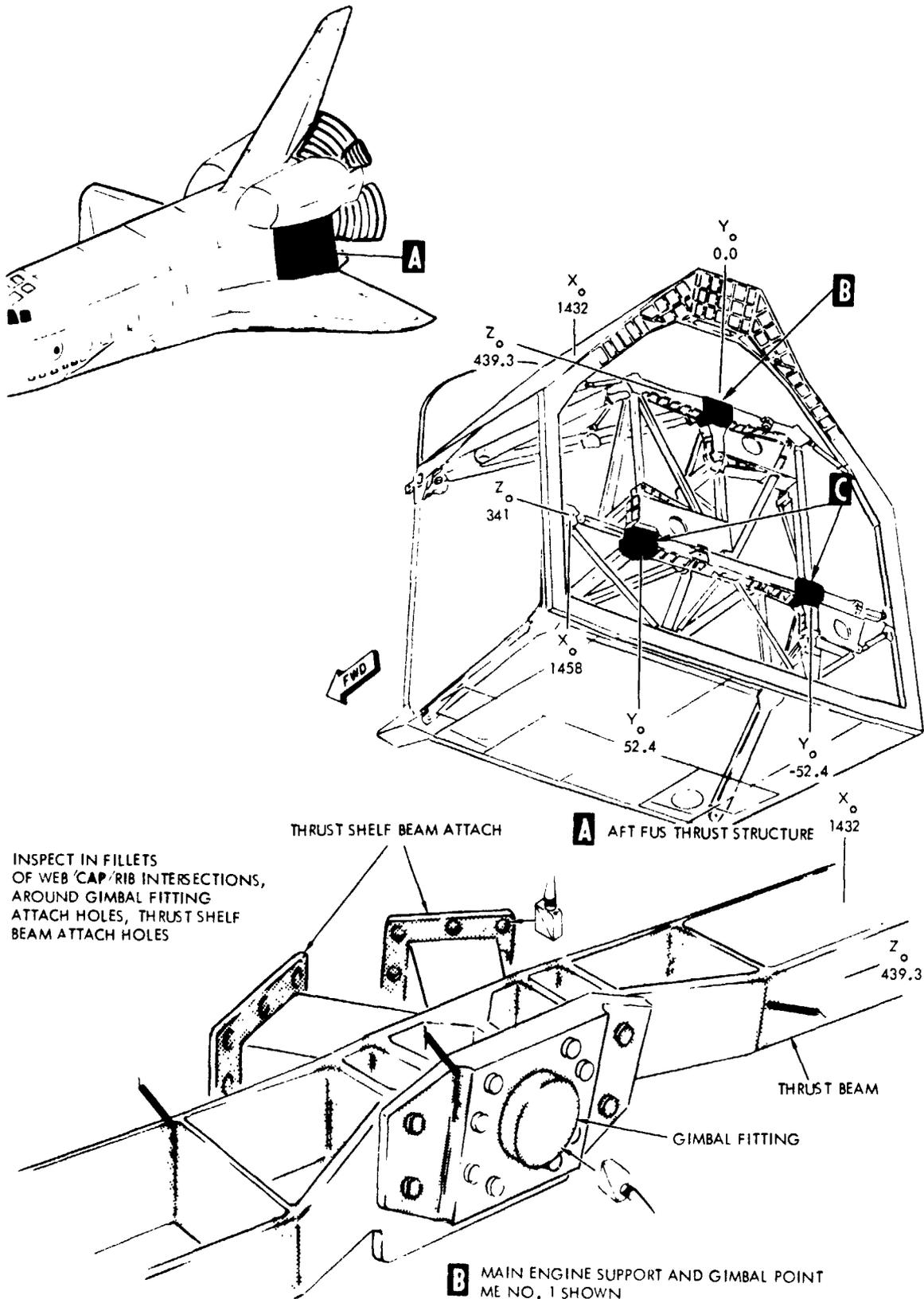
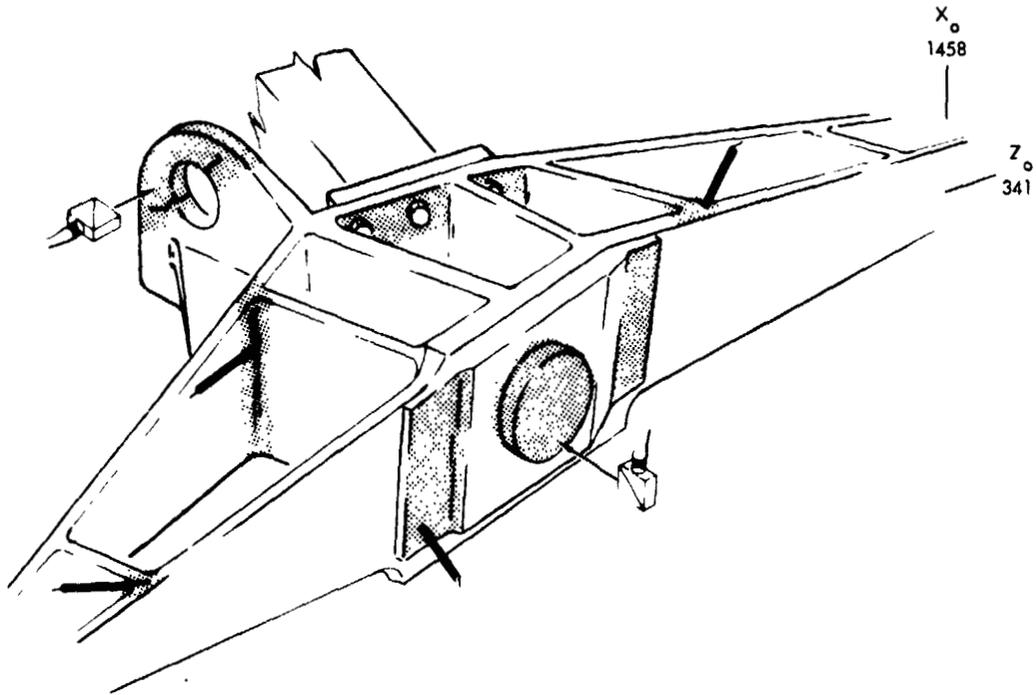


Figure 4-15. Main Engine Support and Gimbal Points (Sheet 1 of 2)



MAIN ENGINE NO. 3, GIMBAL POINTS
ME NO. 2 SIMILAR

Figure 4-15. Main Engine Support and Gimbal Points (Sheet 2 of 2)

PROCEDURE NO. 4-516, Figure 4-16

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-355022

COMPONENT/AREA DESCRIPTION: LOWER THRUST SHELF AND MAIN ENGINE FEEDLINE ATTACHMENTS. Areas on the lower shelf thrust beam where attachments are made to the vertical thrust and lateral trusses and engine feedline supports may initiate fatigue damage due to engine thrust and vibro-acoustic loads reacted through these points. The material of construction for the components is titanium-6Al-4V. The inspection areas consist of lugs, base-plate attachments and lug-to-beam fillets.

DEFECTS: Cracks at bolt holes in both the lower shelf beam and truss lugs and at the lug-base fillets.

ACCESS: Enter the aft fuselage compartment through the aft fus personnel access opening in the aft fus side wall. Removal of bolts may be necessary to apply the backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) and eddy current surface probe (para. 1.5.4.4)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

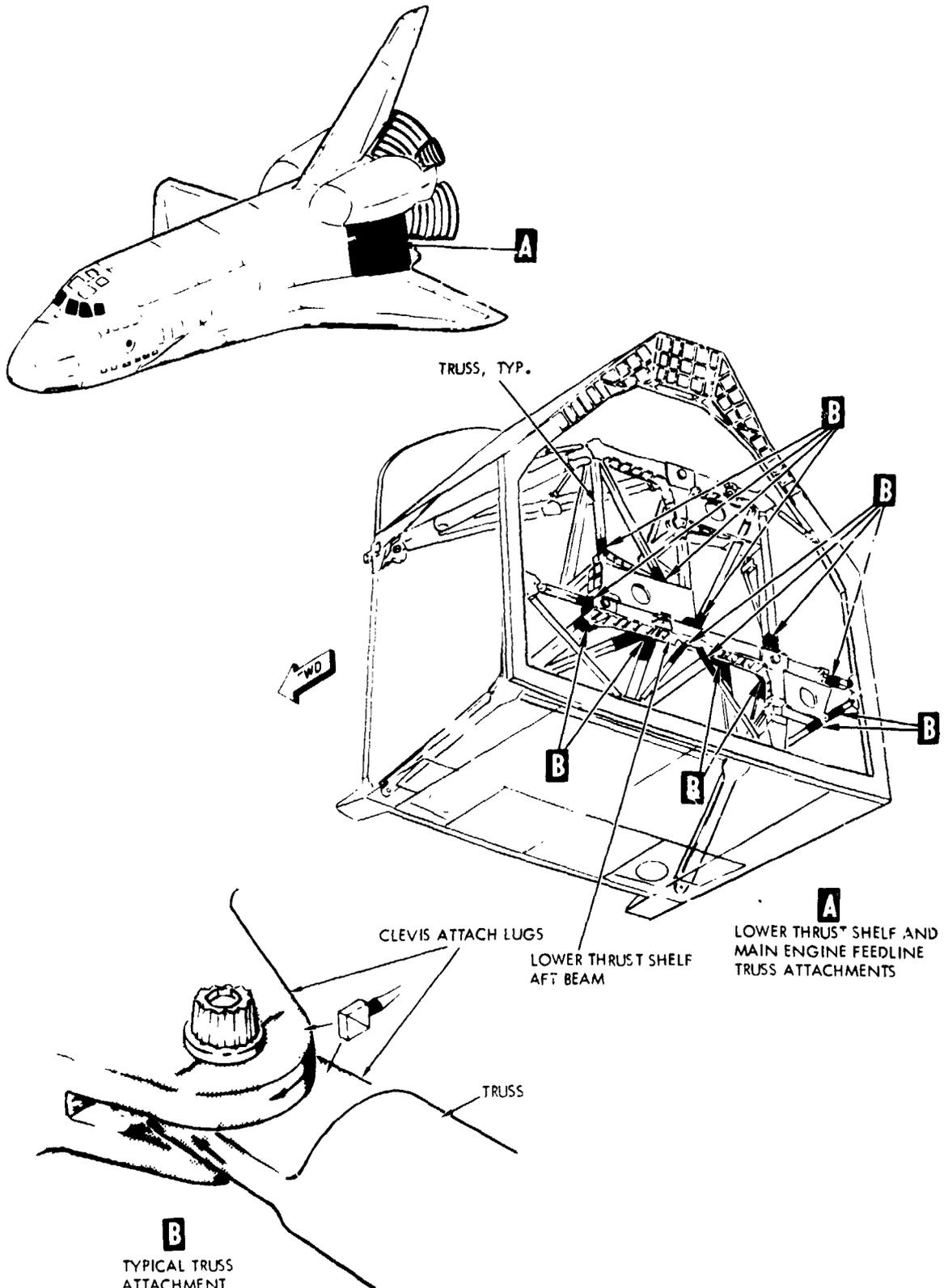


Figure 4-16. Lower Thrust Shelf and Main Engine Feedline Support Attachments

PROCEDURE NO. 4-517, Figure 4-17

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-355022, VL70-355009

COMPONENT/AREA DESCRIPTION: UPPER THRUST SHELF AND MAIN ENGINE NO. 1 FEEDLINE SUPPORT ATTACHMENTS. Areas on the shelf where attachments are made to the upper shelf frame and the vertical thrust support trusses may be susceptible to fatigue damage because of high engine thrust and vibro-acoustic loads which are experienced at these points. The shelf beam is machined from titanium-6Al-4V alloy. The points are located at the outboard attachment areas to the vertical support trusses, the ME #1 feedline support trusses, and at the attachments to the upper shelf frame.

DEFECTS: Cracks around bolt holes in lugs or where the lug blends into the base.

ACCESS: Enter the aft fuselage compartment through the aft fus personnel access opening in the aft fus side wall. For back-up inspection, the suspect truss member may have to be disconnected and the area stripped of surface finish.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for lug-base fillets

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

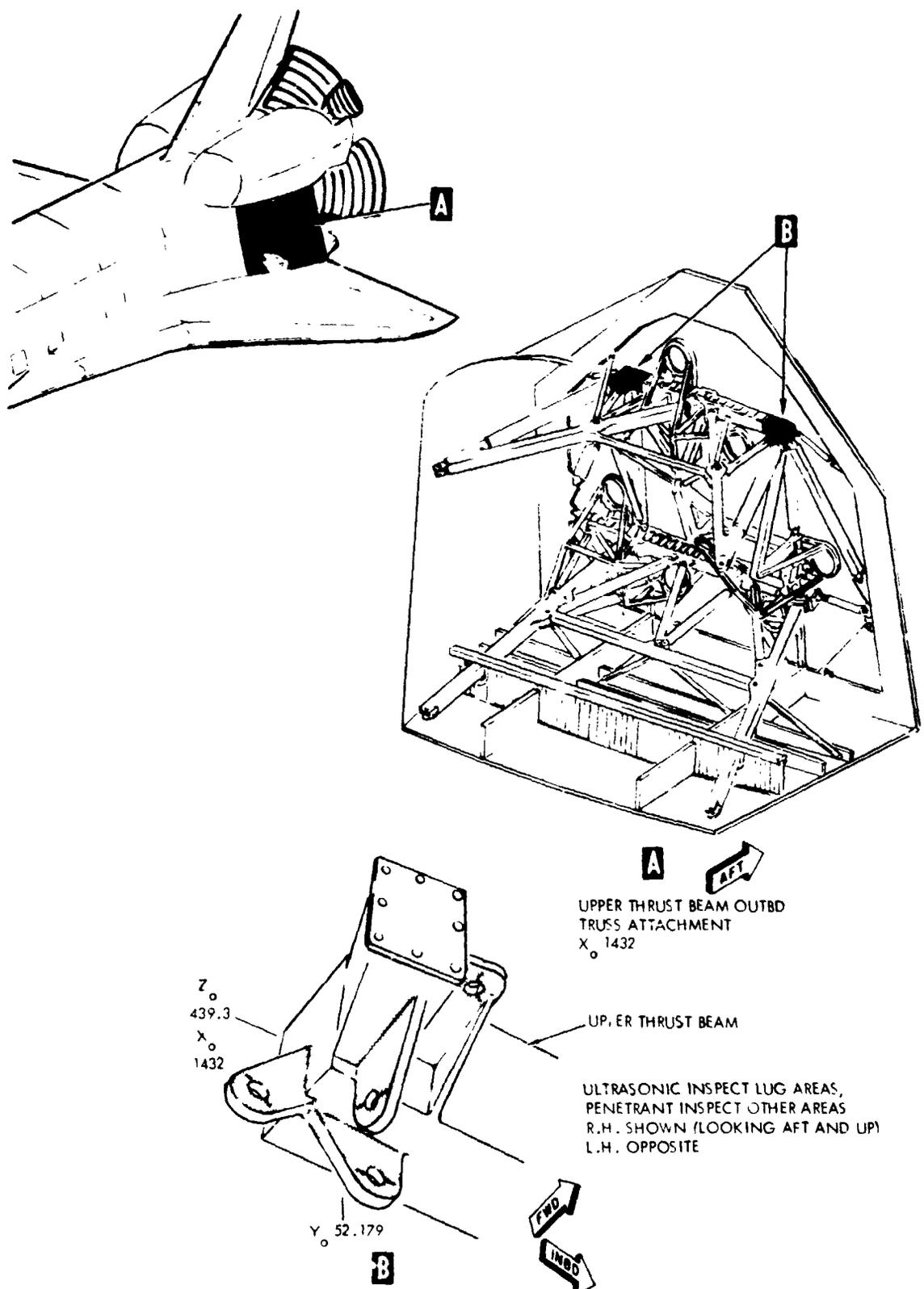


Figure 4-17. Upper Thrust Shelf and Main Engine #1 Feedline Support Attachments

PROCEDURE NO. 4-518, Figure 4-18

<u>MAJOR ASSEMBLY:</u>	ORBITER, AFT FUSELAGE, ZONE 5	<u>TYPE INSPECTION</u> (X) POSTFLIGHT
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SUBASSEMBLY: CANTED FRAME

DRAWING(S): VL70-355050; VL70-355022, VL70-005100

COMPONENT/AREA DESCRIPTION: CANTED FRAME (LWR PORTION). The canted frame is a principal member of the aft fuselage internal thrust structure which has clevis attachments for the main engine support structure and is spliced at the Z_o 415.77 water plane. The lower portion of the frame is a Ti-6Al-4V titanium alloy machined plate member which attaches directly to the main engine actuator support structure. The frame partially reacts fin drag and engine thrust loads. An engine-out condition will cause unsymmetric loads affecting actuator structure attachment points and frame splices.

DEFECTS: Radial cracks in lug holes providing canted frame-to-engine actuator structure attachments; part-through cracks at the base of attachment lugs; radial cracks in bolt holes at canted frame splice joints at Z_o 415.77.

ACCESS: Enter aft fuselage thrust compartment lower section. Remove bolt from truss member attachment lugs as necessary for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for lugs and longitudinal wave (para. 1.5.5.3 A) for splice pulse-echo techniques.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9) for lug base; Eddy current bolt hole for bolt holes (para. 1.5.4.3).

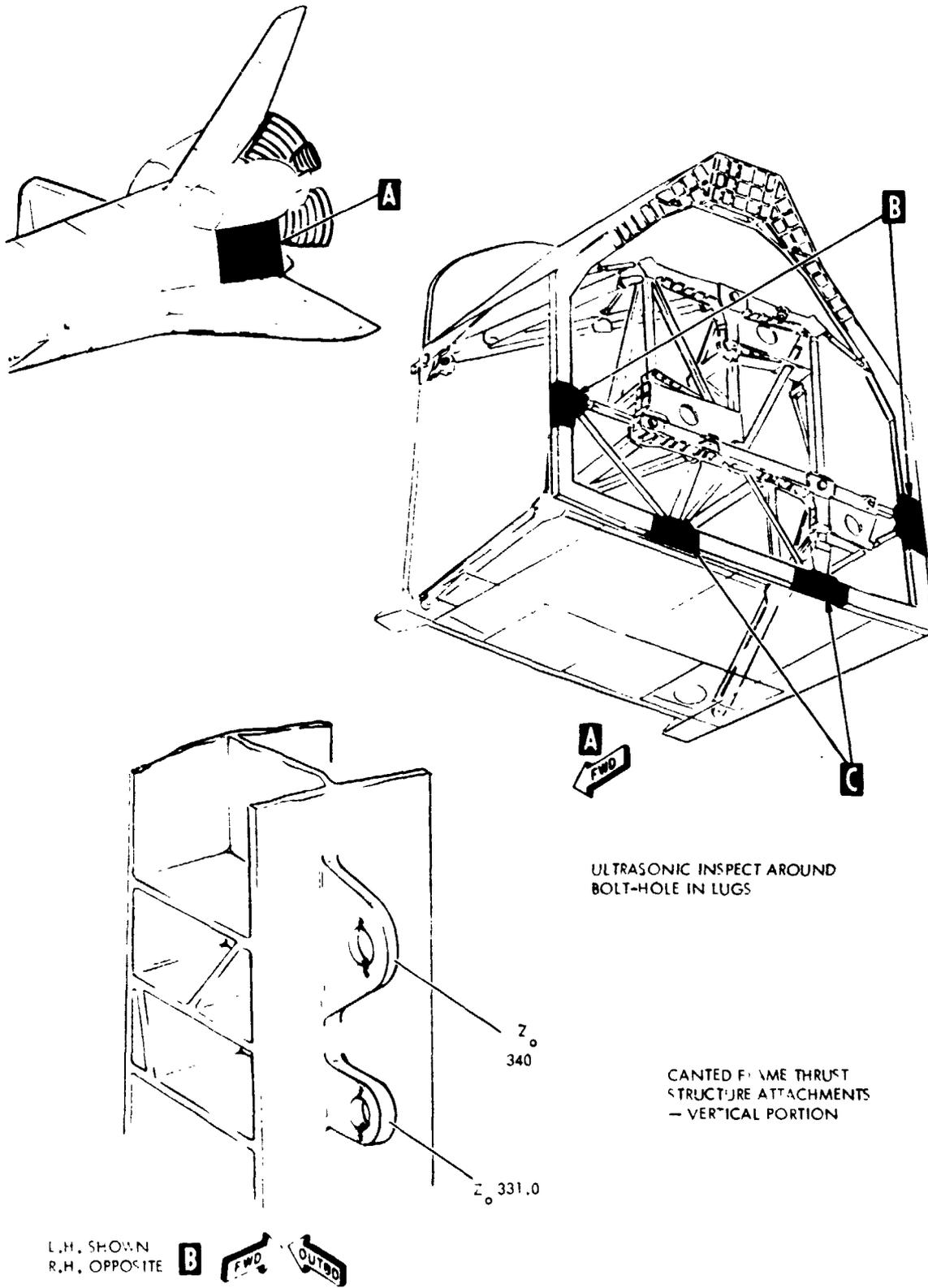


Figure 4-18. Canted Frame - Lower Portion (Sheet 1 of 2)

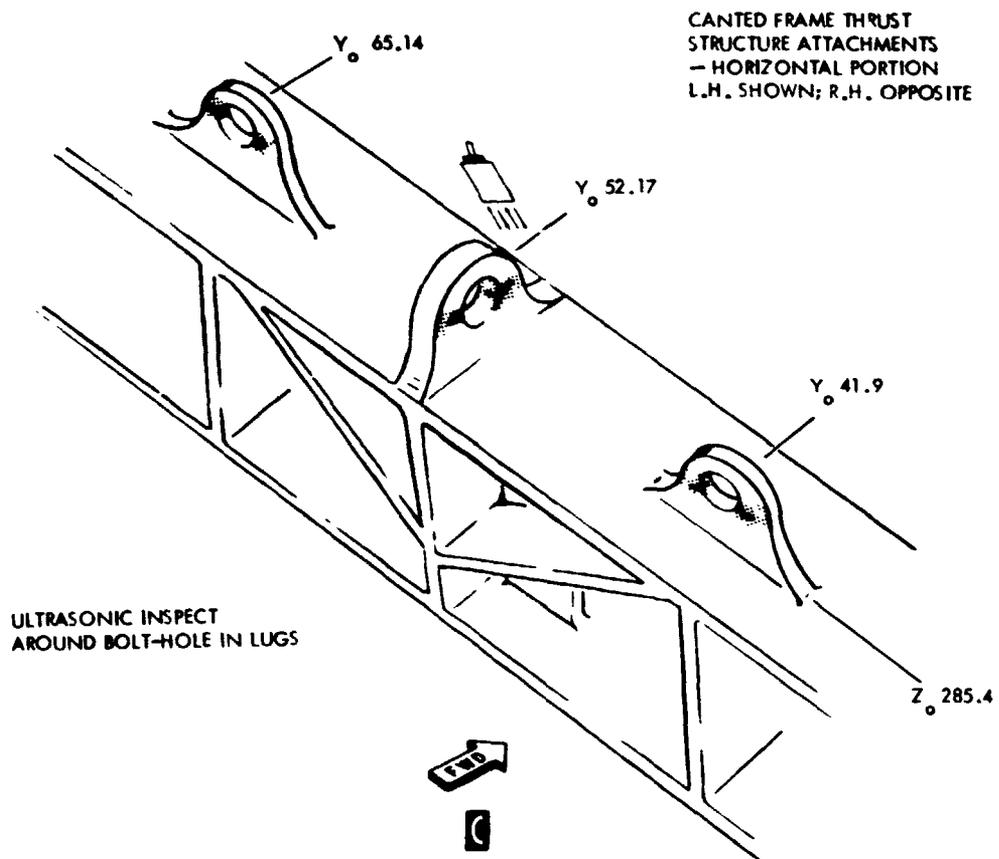


Figure 4-18. Canted Frame - Lower Portion (Sheet 2 of 2)

PROCEDURE NO. 4-519, Figure 4-19

	<u>TYPE OF INSPECTION</u>
<u>MAJOR ASSEMBLY:</u> ORBITER, AFT FUSELAGE, ZONE 5	(X) POSTFLIGHT
<u>SUBASSEMBLY:</u> CANTED FRAME	
<u>DRAWING(S):</u> VL70-355050, VL70-355022, VL70-005100, VL70-005017	

COMPONENT/AREA DESCRIPTION: CANTED FRAME (UPR PORTION).

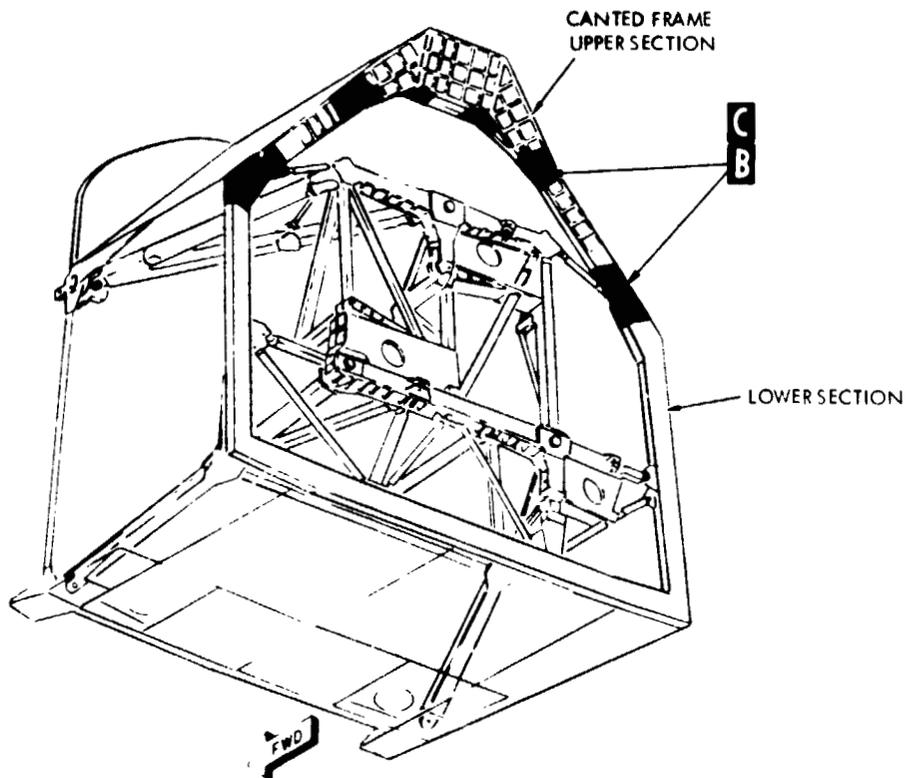
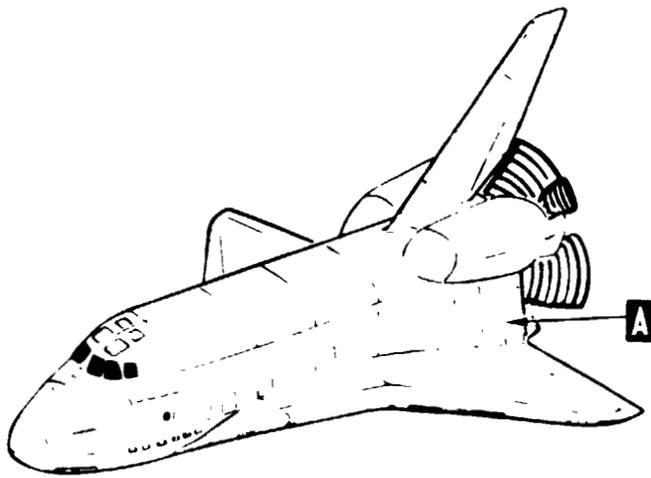
The canted frame is a principal member of the main engine thrust structure, having clevis attach points for the main engine support frames and is spliced at the Z_o 415.77' water plane. The upper portion of the canted frame is machined from 2124-T851 aluminum alloy plate (lwr half) and diffusion bonded titanium-6Al-4V alloy (upper half), and provides support for the vertical fin and has lateral attachments for the main engine support frames. It is spliced to the titanium lower canted frame. An engine-out condition will cause unsymmetric loads affecting actuator structure attachment points and frame splices.

DEFECTS: Radial cracks in the lug holes which provide canted frame-to-engine actuator structure attachments and in bolt holes at the canted frame splice at Z_o 415.77; part-through cracks at the base of attachment lugs; edge cracks along titanium upper portion of frame cap.

ACCESS: Enter aft-fuselage thrust compartment upper section. Remove bolts from truss member attachment lugs as necessary for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for lugs and splices and eddy current surface probe (para. 1.5.4.4).

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9) for lug base; eddy current bolt hole for bolt holes (para. 1.5.4.5).



A

THRUST STRUCTURE CANTED FRAME, UPPER SECTION

FIG 4-19. Canted Frame - Upper Portion (Sheet 1 of 2)

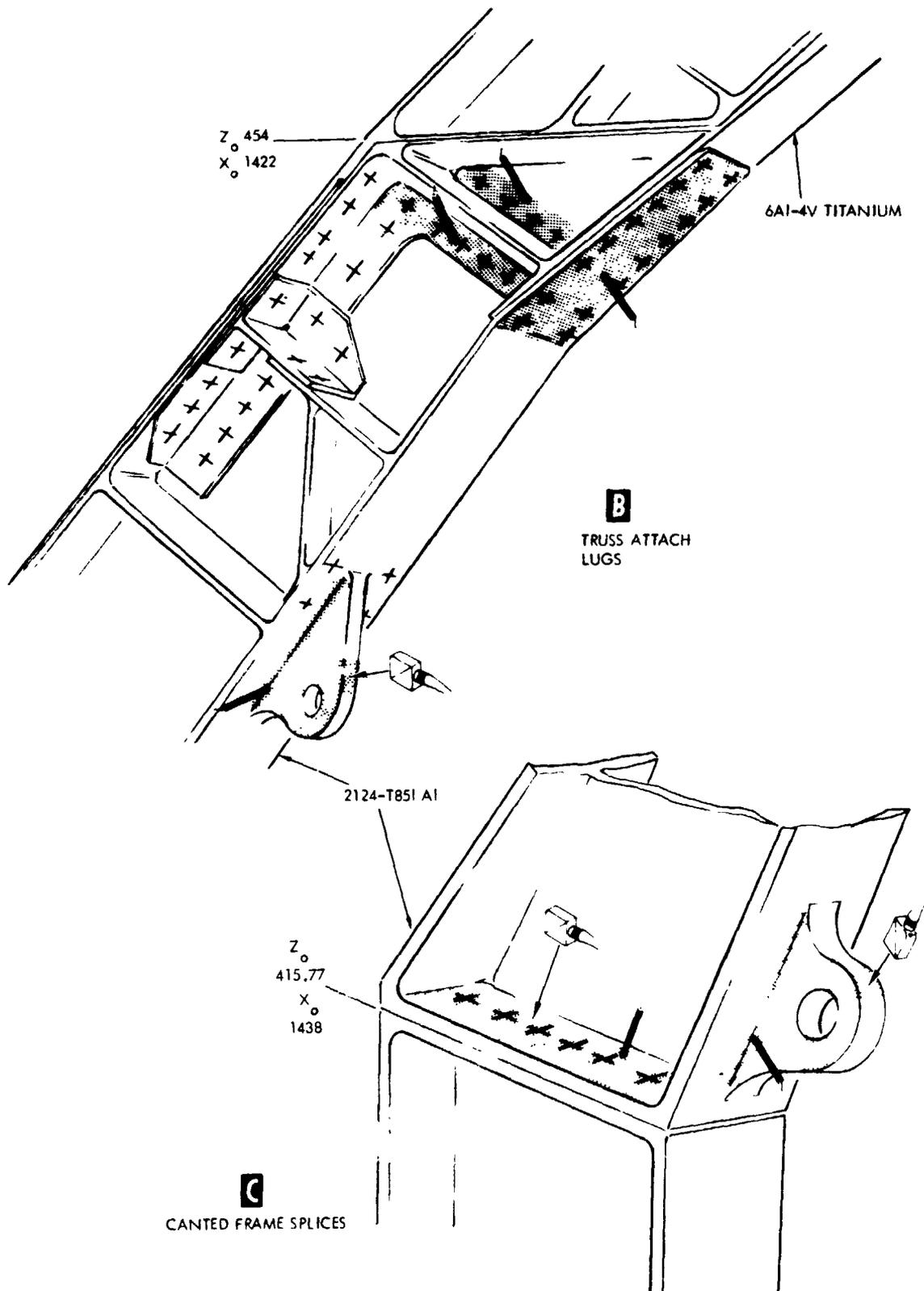


Figure 4-19. Canted Frame - Upper Portion (Sheet 2 of 2)

PROCEDURE NO. 4-520, Figure 4-20

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: THRUST STRUCTURE

DRAWING(S): VL70-355022

COMPONENT/AREA DESCRIPTION: VERTICAL THRUST TRUSS

ATTACHMENTS (LH, RH AND CENTER). The upper and lower thrust shelves are stabilized by three interconnecting titanium-6Al-4V thrust plane trusses which are reinforced by additional trusses. The clevis attachment areas common to the vertical trusses and their support trusses may experience fatigue damage due to main engine thrust and vibroacoustic loads.

DEFECTS: Radial cracks at clevis bolt holes in attachment lugs and pads and part-through cracks at the lug-base fillets.

ACCESS: Enter aft fuselage thrust compartment, upper and lower areas, through the aft fus access door or the base-heat shield access opening. Backup inspection may require disconnection of suspect truss clevis joint.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for lug clevis attachment areas and eddy current (para. 1.5.4.4) for lug fillets.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

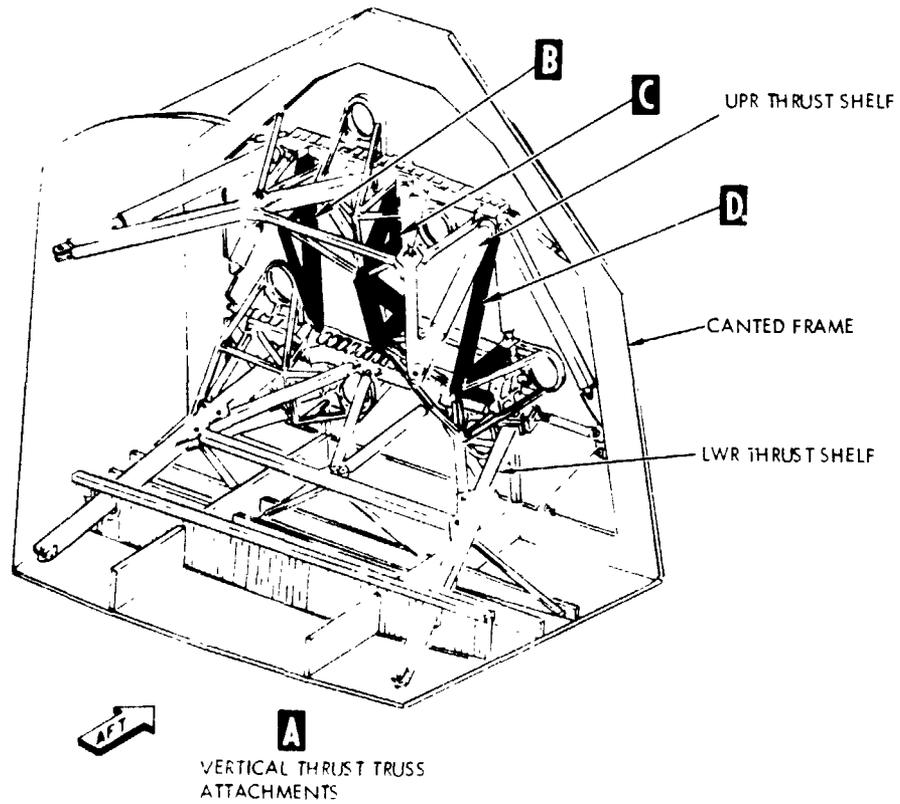
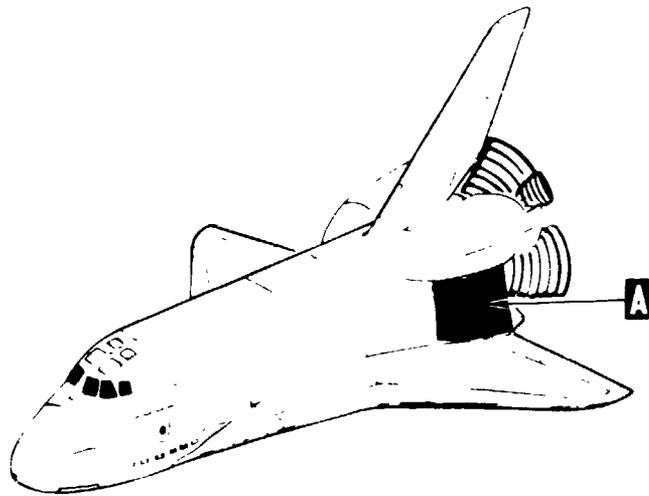


Figure 4-20. Vertical Thrust Truss Attachments (Sheet 1 of 3)

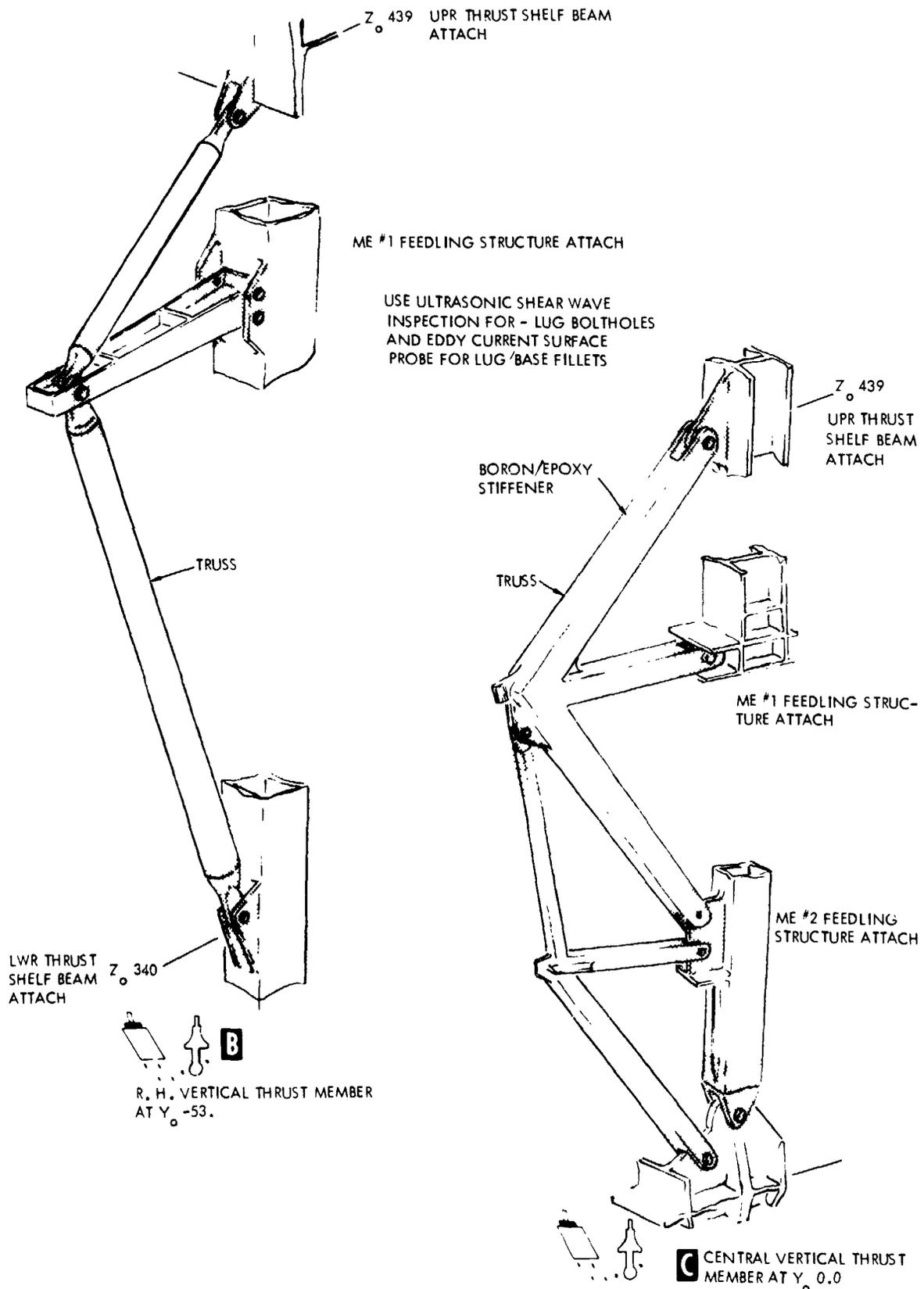


Figure 4-20. Vertical Thrust Truss Attachments (Sheet 2 of 3)

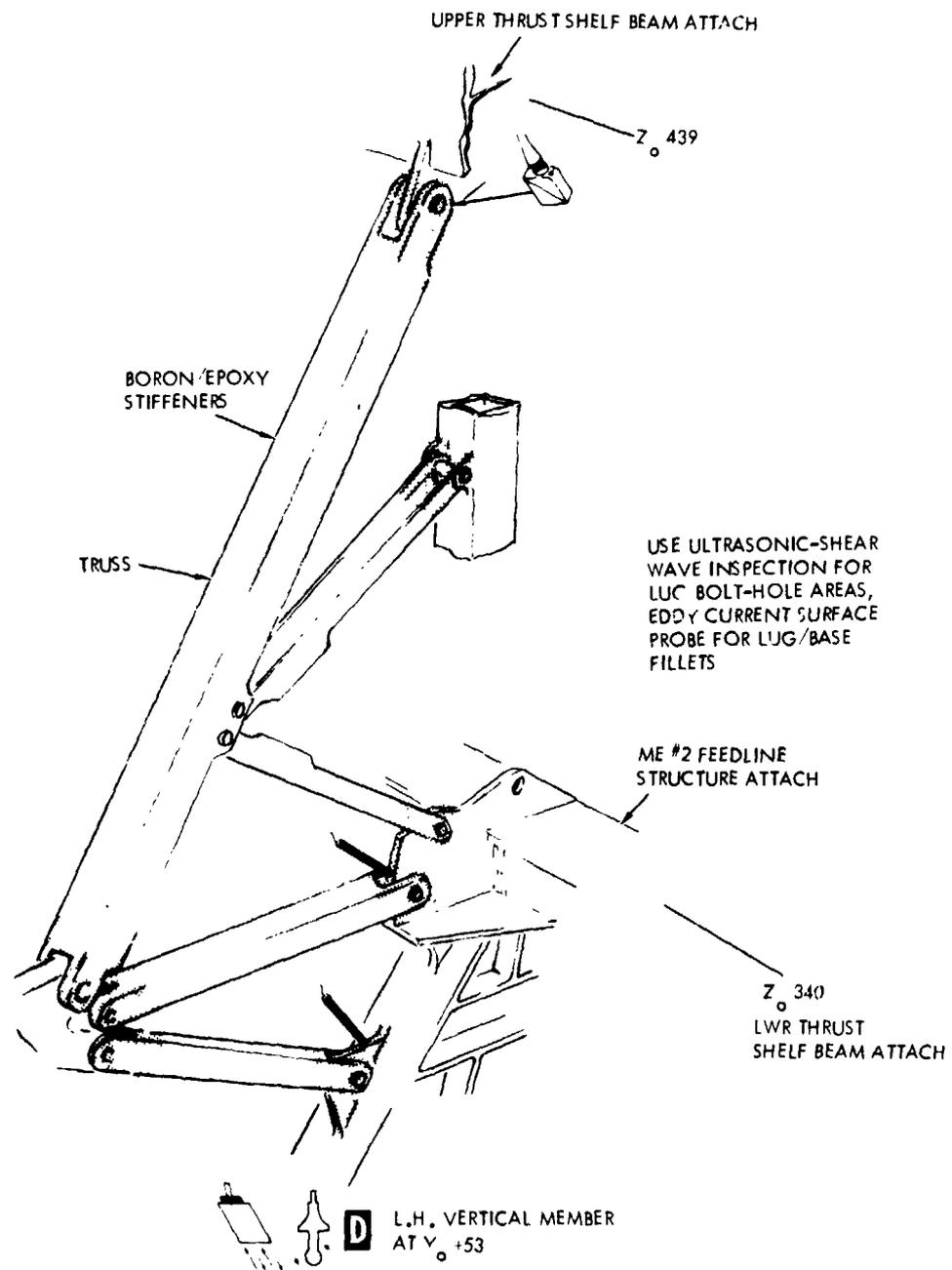


Figure 4-20. Vertical Thrust Truss Attachments (Sheet 3 of 3)

PROCEDURE NO. 4-521, Figure 4-21

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: AFT FUS/VERT. STAB INTERFACE

DRAWING(S): VL70-005107; VL70-355051

COMPONENT/AREA DESCRIPTION: FIN SUPPORT FRAME, CLEVIS ATTACH

AREA. This safe-life component forms the upper end of the vertical fin support frame and contains the clevis attach lugs that mate with the vertical stabilizer-fuselage aft attach plate. This component transfers the vertical stabilizer rear spar loads into the aft fus structure. The frame is made of titanium-6Al-4V alloy in the annealed temper, and is located at $X_o = 1426$, $Z_o = 513$, and $Y_o = \pm 16.5$. Flight loads imposed through the vertical stabilizer rear spar attachment may produce fatigue damage in the clevis bolt holes.

(Coordinate with inspection of vert stab-fus aft attach plate)

DEFECTS: Corner or through-cracks at the edge of the clevis bolt holes in the attachment lugs.

ACCESS: (TBD) For eddy current bolt hole, clevis bolt must be removed - only one at a time.

NDT TECHNIQUES: Primary: Use eddy current bolt hole probe (para. 1.5.4.3) with clevis bolt removed - or if top edge of attachment flanges are accessible, use ultrasonic p.e. longitudinal wave (para. 1.5.5.3 A); use eddy current (para. 1.5.4.4) for fillets.

Backup: If ultrasonic technique is used in primary inspection use eddy current bolt hole for backup (para. 1.5.4.3)

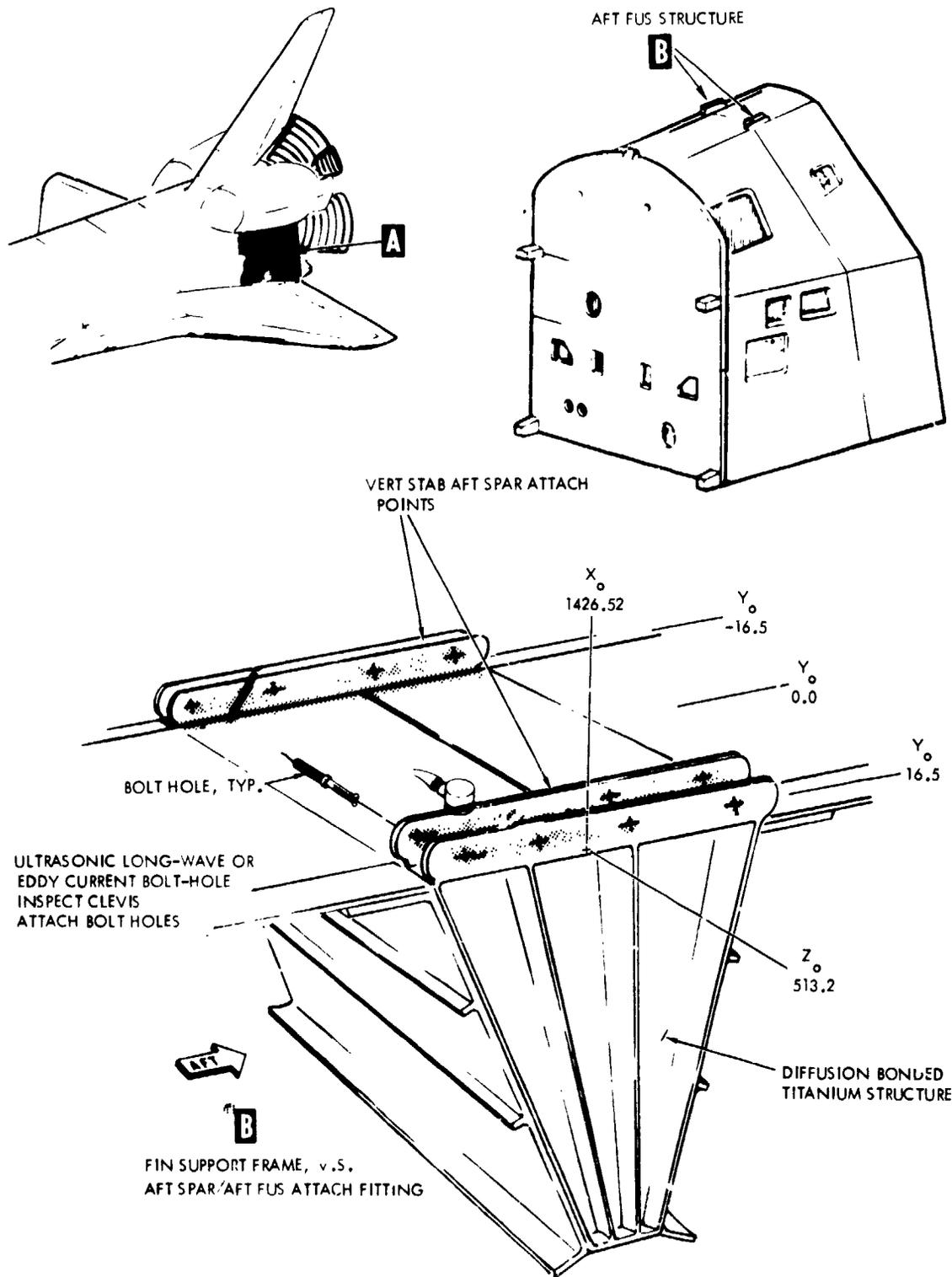


Figure 4-21. Fin Support Frame, Clevis Attach

PROCEDURE NO. 4-522, Figure 4-22

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: BASE HEAT SHIELD

DRAWING(S): VL70-355101

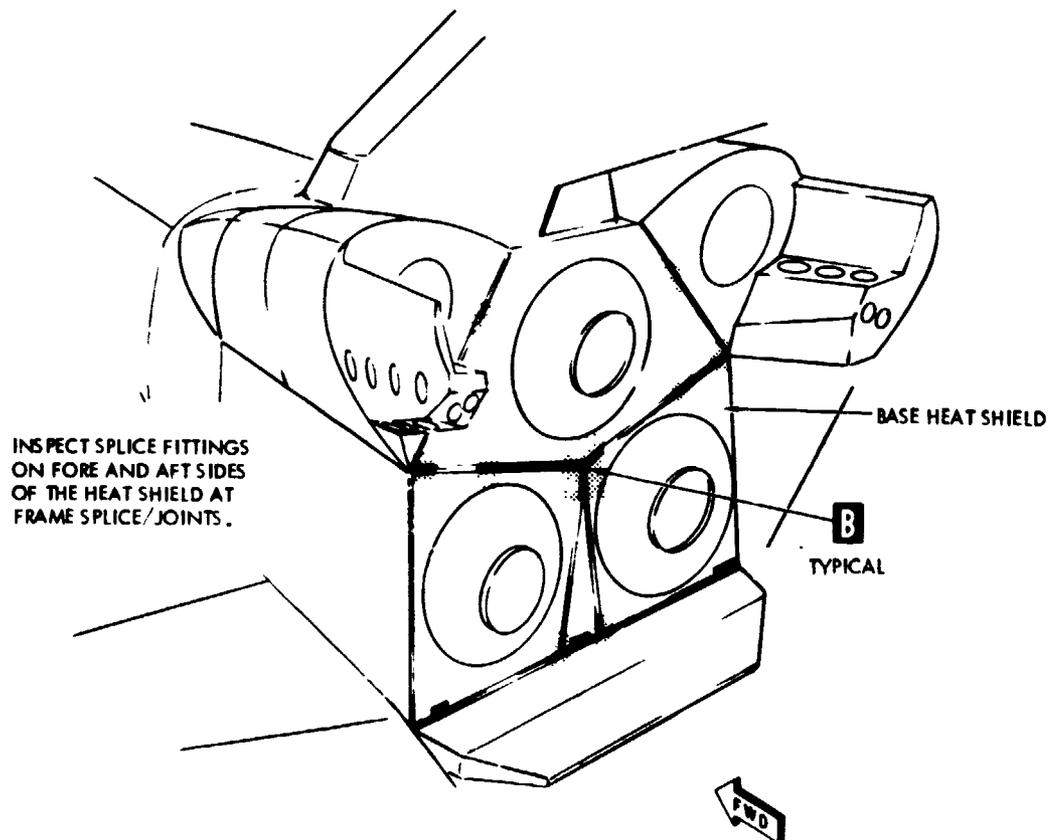
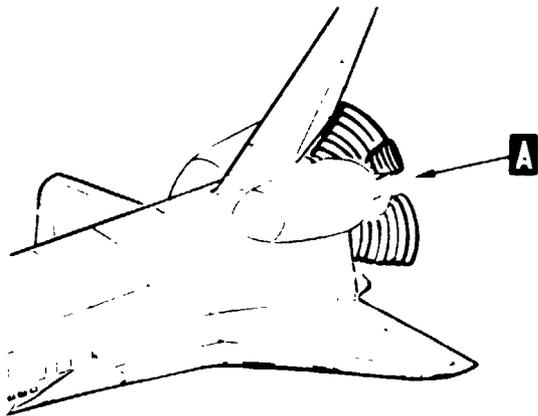
COMPONENT AREA DESCRIPTION: BASE HEAT SHIELD FRAMING

STRUCTURE. The base heat shield is a complex structure that provides closeout of the base area of the aft fuselage. It consists of aluminum honeycomb flat panels covered with LRSI/TPS tiles and bulge-stiffened inconel hot-structure sections with internal insulation all connected to a 2024 aluminum alloy frame. The removable bulged sections contain large penetrations for the main engine skirts. The heat shield must withstand severe temperature requirements from engine blast, ascent pressure differentials and extreme vibroacoustic loads during liftoff and ascent. The base heat shield is located at about X₀ 1519 lower aft edge and at X₀ 1463, upper fwd edge.

DEFECTS: Cracks in the frame intersections, both frame-frame intersections and frame-fuselage intersections.

ACCESS: Access to the frame areas is attained from the aft fuselage compartment upper level and the compartment between the base heat shield and canted bulkhead. Enter the aft fus access opening or the base heat shield aft access opening.

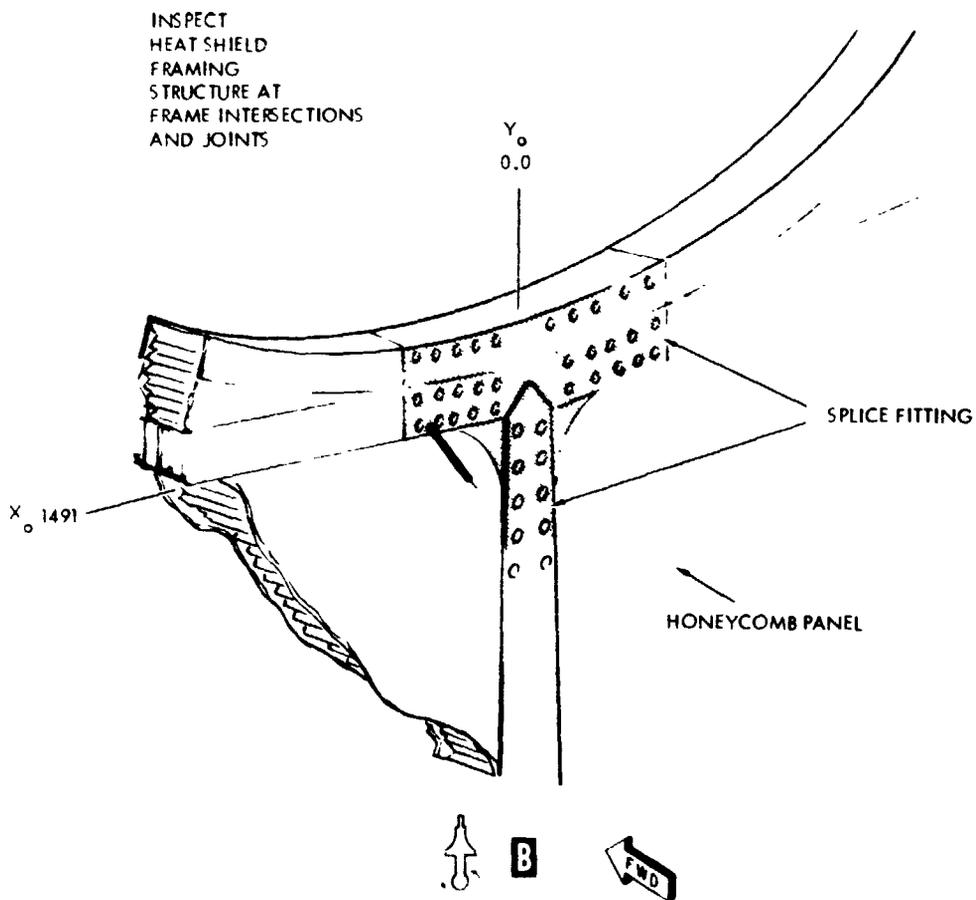
NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4)
Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



A

AFT FUS BASE HEAT SHIELD FRAMING STRUCTURE

Figure 4-22. Base Heat Shield Framing Structure (Sheet 1 of 2)



HEAT SHIELD CENTRAL FRAME INTERSECTION, TYPICAL.
OTHER INTERSECTION AS INDICATED ON LOCATOR SKETCH.

Figure 4-22. Base Heat Shield Framing Structure (Sheet 2 of 2)

PROCEDURE NO. 4-523, Figure 4-23

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: BASE HEAT SHIELD

DRAWING(S): VL70-355101

COMPONENT/AREA DESCRIPTION: BASE HEAT SHIELD DOME JUNCTURES.

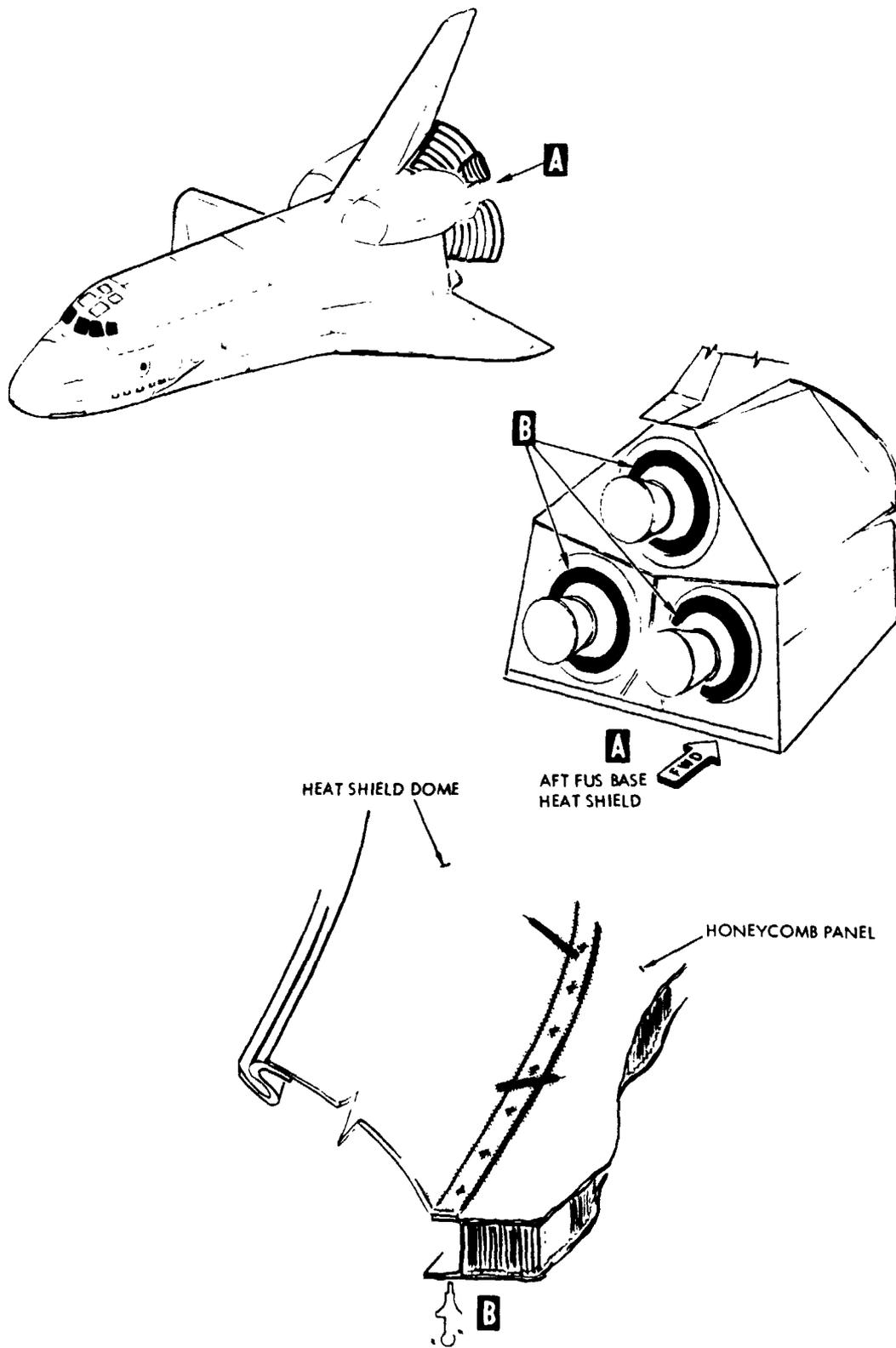
The base heat shield domes are inconel alloy annular segments which are attached to the aluminum honeycomb panels and interface with the main engine skirts through an intermediate seal. Atmospheric pressure differentials and extreme vibroacoustic loads during liftoff and ascent may produce damage at the dome attachments to the honeycomb panels.

DEFECTS: Cracks in the dome attachment flange and honeycomb closeout flange.

ACCESS: The areas are accessible from outside of the aft fuselage, aft of the base heat shield; also from the compartment forward of the base heat shield which is entered through the base heat shield aft access opening.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



BASE HEAT SHIELD DOME TO HONEYCOMB ATTACH

Figure 4-23. Base Heat Shield Dome Structures

PROCEDURE NO. 4-524, Figure 4-24

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: OMS POD/AFT FUS

DRAWING(S): VL70-005016, VL70-008376

COMPONENT/AREA DESCRIPTION: OMS POD ATTACH POINTS TO AFT FUSELAGE. The OMS pod is attached to the aft fuselage OMS deck with steel bolts and bushings and aluminum alloy or stainless steel fittings. The interfacial structure is 2024 aluminum alloy skin/stringer/frame material finished with zinc chromate primer. The attach areas receive some stresses from vertical fin shear loads, engine thrust and vibroacoustic loads. A main-engine-out condition may cause overload conditions in the aft fuselage structure which may be transferred to the OMS pods through the attach fittings.

DEFECTS: Cracks in bolt and fastener hole in the attach fittings and the adjoining aluminum structure.

ACCESS: Access to the attachment areas is from outside the aft fuselage, inside the aft fuselage upper compartment and inside the OMS pod. Access panels in the aft fus OMS deck, and OMS pod fore and aft bulkheads will facilitate inspection. The exterior pod surface is protected by RSI/TPS panels.

NDT TECHNIQUES: Primary: Optical (para. 1.5.1.3), radiographic (para. 1.5.6.2) and eddy current (para. 1.5.4.4).

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9) and eddy current bolt hole (para. 1.5.4.3).

PROCEDURE NO. 4-525, Figure 4-25

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: OMS DECK (AFT FUS UPR
SHELL STRUCT)

DRAWING(S): VL70-355028, VL70-355035

COMPONENT/AREA DESCRIPTION: UPPER LONGERON, OMS DECK.

The longeron along the OMS deck-upper aft fuselage intersection at Z_o 476 is composed of forward and aft segments extending from X_o 1307 to X_o 1462 and joined by a 2124 aluminum alloy fitting at X_o 1432. Each segment is made of 2124 aluminum alloy. The longeron joins skin panels and frame along the upper edge of the OMS pod and experiences some of the torsional and shear load from the vertical stabilizer. Skin and splice plates conceal the flange fillet areas from the interior and the OMS pod conceals them from the exterior.

DEFECTS: Longitudinal part-through cracks where the inboard and outboard legs join the central body of the longeron near the runout ends of both forward and aft segments.

ACCESS: Access for employing radiographic inspection is gained by entering the aft fuselage compartment upper area and from outside the aft fuselage shell, both inside and outside the OMS pod. Some disassembly may be necessary to verify suspected cracks after primary inspection.

NDT TECHNIQUES: Primary: Radiographic (para. 1.5.6.2)
Backup: Eddy current (para. 1.5.4.4)

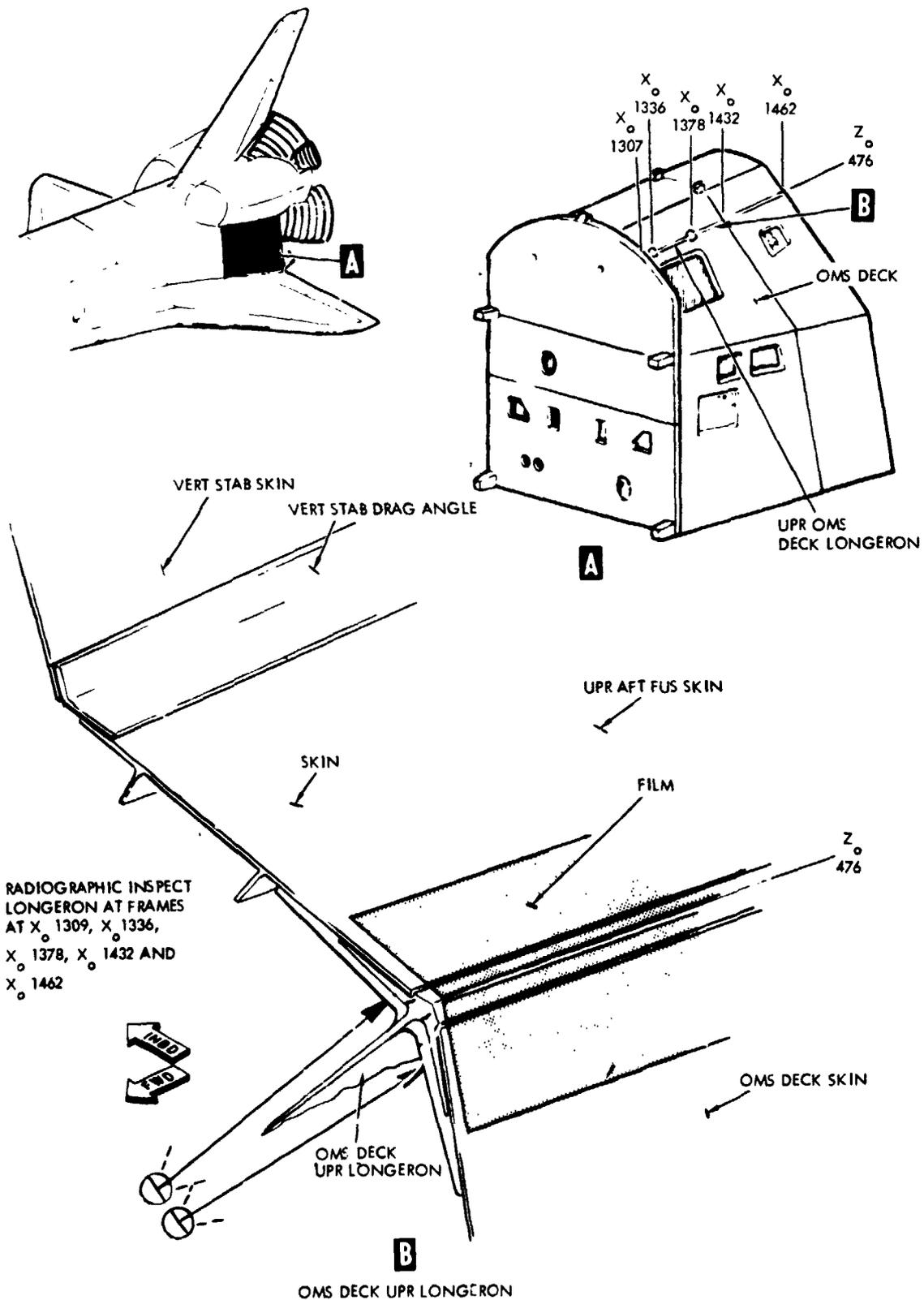


Figure 4-25. Upper Longeron, OMS Deck

PROCEDURE NO. 4-526, Figure 4-26

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: OMS POD

DRAWING(S): VL70-005016 (PRR), VL70-008376

COMPONENT/AREA DESCRIPTION: OMS ENGINE GIMBAL ACTUATOR

ATTACH. The OMS engine pitch and yaw actuators are attached to fittings located just forward of the OMS aft firewall at X_p 298 and Z_p 89 and Z_p 126. The fittings are made of 2024 aluminum alloy and have a zinc chromate and Supercorapon 515-700 paint surface finish. They receive actuator reaction loads during engine gimbaling in orbital maneuvers and entry.

DEFECTS: Radial cracks in the clevis attach lug bolt hole. Cracks in fastener holes in the fitting base-to-pod attach areas.

ACCESS: Access is from outside the aft fuselage above the main engines. Remove the OMS aft fire wall removable panel.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for lug-bolt hole areas and eddy current surface probe (para. 1.5.4.4) for base attachment areas.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

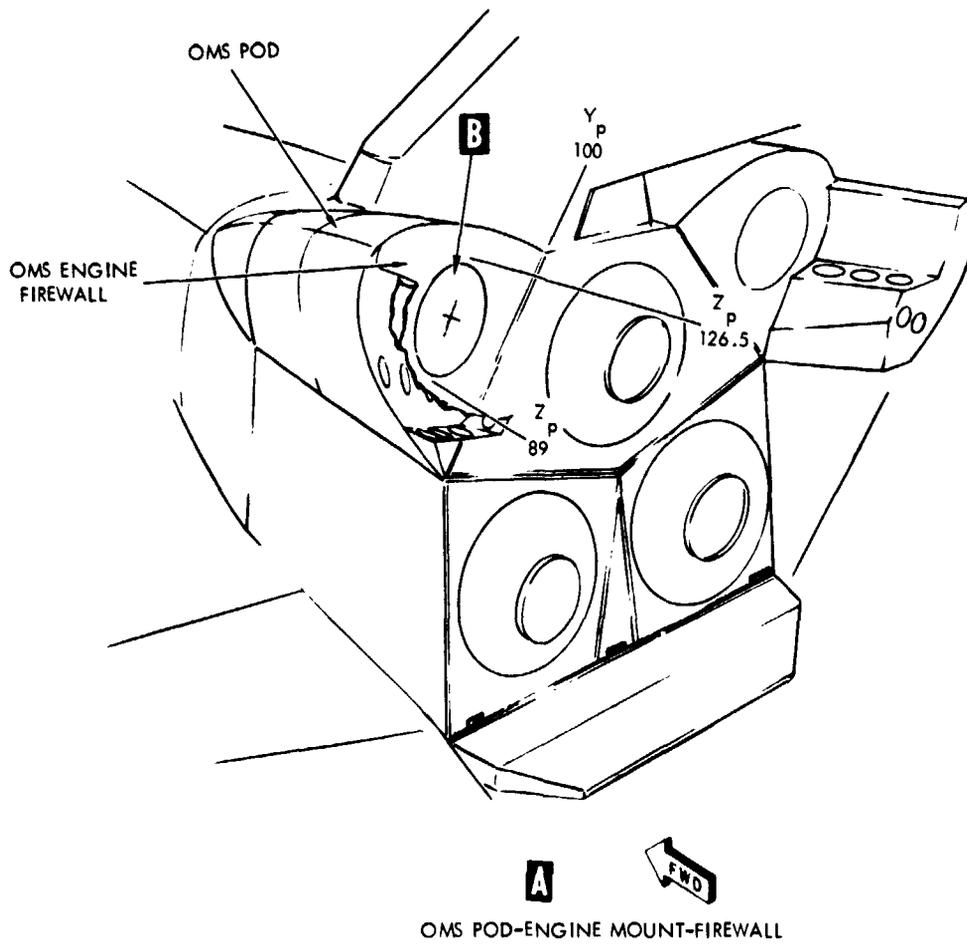
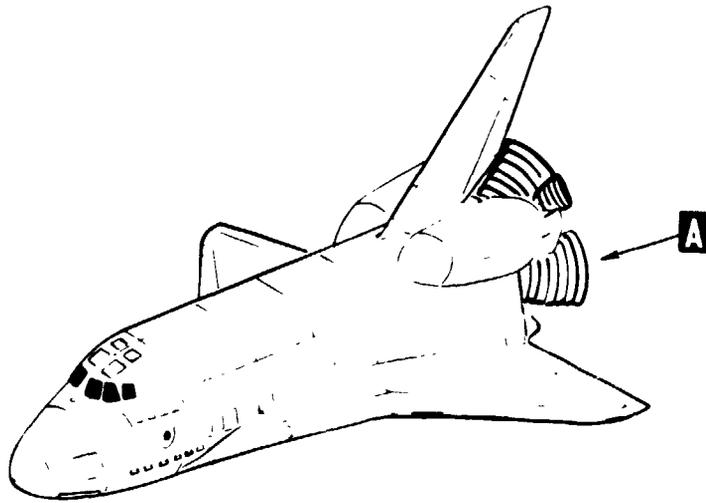


Figure 4-26. OMS Engine Gimbal Actuator Attach (Sheet 1 of 2)

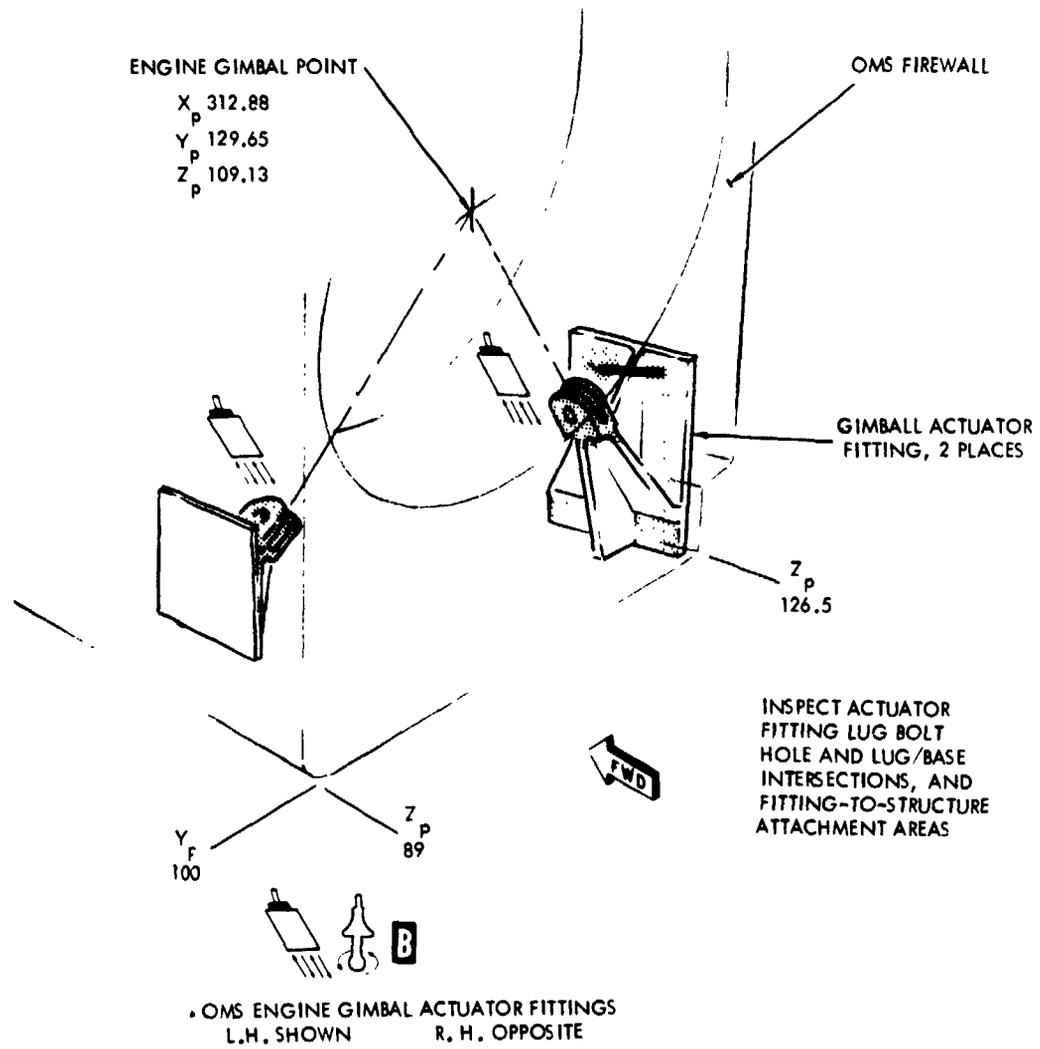


Figure 4-26. OMS Engine Gimbal Actuator Attach (Sheet 2 of 2)

PROCEDURE NO. 4-527, Figure 4-27

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE, ZONE 5

TYPE INSPECTION
(X) POSTFLIGHT

SUBASSEMBLY: OMS POD

DRAWING(S): VL70-005016 (PRR), VL70-008376

COMPONENT/AREA DESCRIPTION: OMS ENGINE THRUST SUPPORT

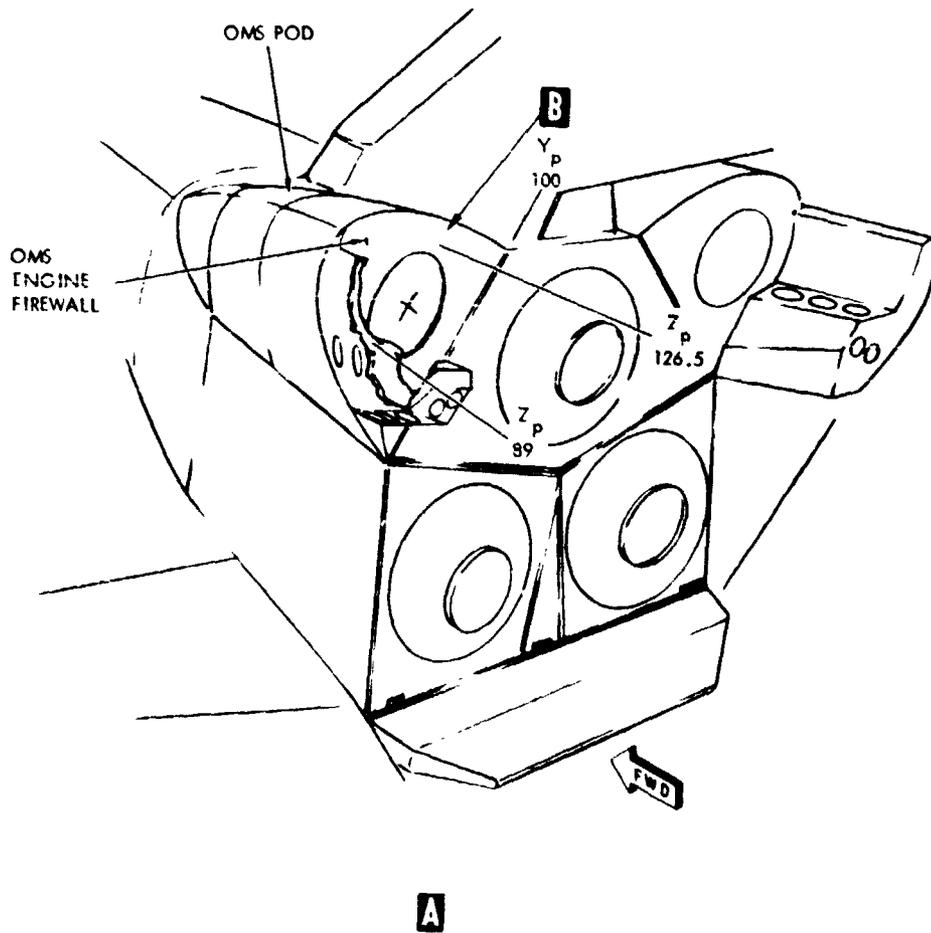
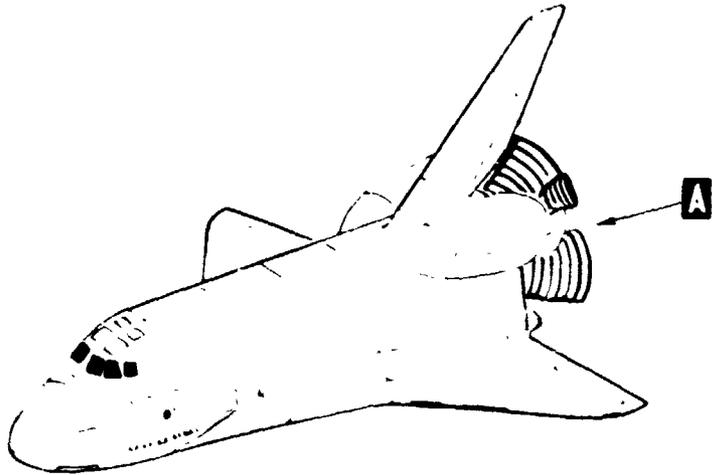
STRUCTURE. The OMS engine thrust support structure consists of 2024 (or 2124) aluminum alloy thrust fittings, trusses and attach fittings. The two thrust fittings are located along the OMS Y_p 123.75 and Y_p 134.33 planes, respectively, at approximately OMS water plane Z_p 109.75 and extend slightly aft of the OMS station X_p 304. The trusses attach to the thrust fittings and mate to the truss attach fittings on Y_p 150 bulkhead. These members receive loads from the OMS engines only during orbital maneuvering and deorbit.

DEFECTS: Fatigue cracks around truss attach clevis lug bolt holes and in the fillet where the lugs blend into their base. Also cracks around fastener holes where the thrust fitting and truss attach fittings mate to the support frames.

ACCESS: These areas are accessible from a point outside the aft fuselage above the main engines. Removal of the OMS engine base heat shield will be necessary.

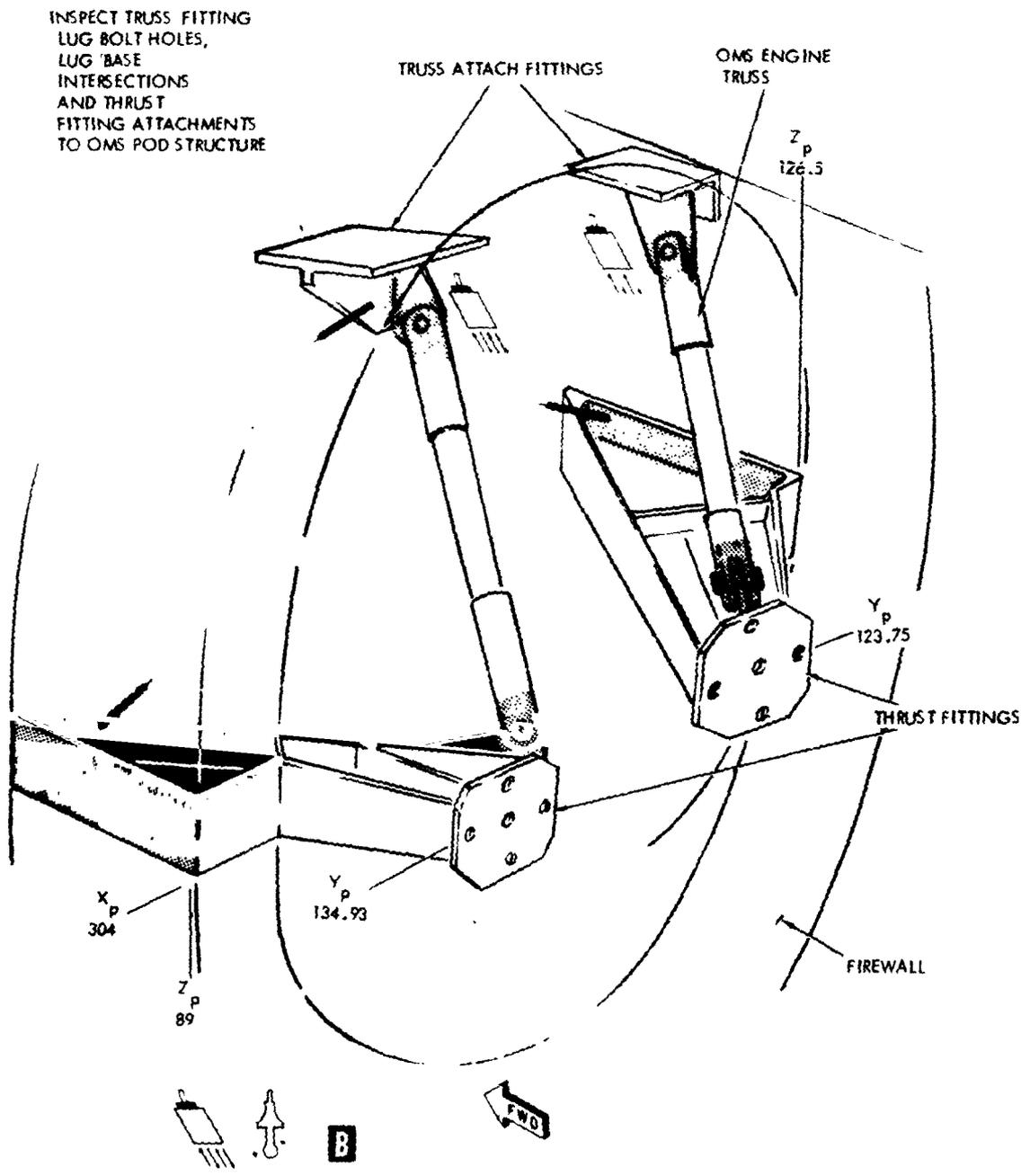
NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for the clevis lug bolt holes and eddy current (para. 1.5.4.4) for all other areas.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



A
OMS POD - ENGINE MOUNT - FIREWALL

Figure 4-27. OMS Engine Thrust Support Structure (Sheet 1 of 2)



OMS THRUST FITTINGS AND TRUSSES
L.H. SHOWN, R. H. OPPOSITE

Figure 4-27. OMS Engine Thrust Support Structure (Sheet 2 of 2)

PROCEDURE NO. 4-528, Figure 4-28

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: OMS/RCS POD

DRAWING(S): VL72-000091, VL70-008376

COMPONENT/AREA DESCRIPTION: AFT RCS POD ATTACH STRUCTURE.

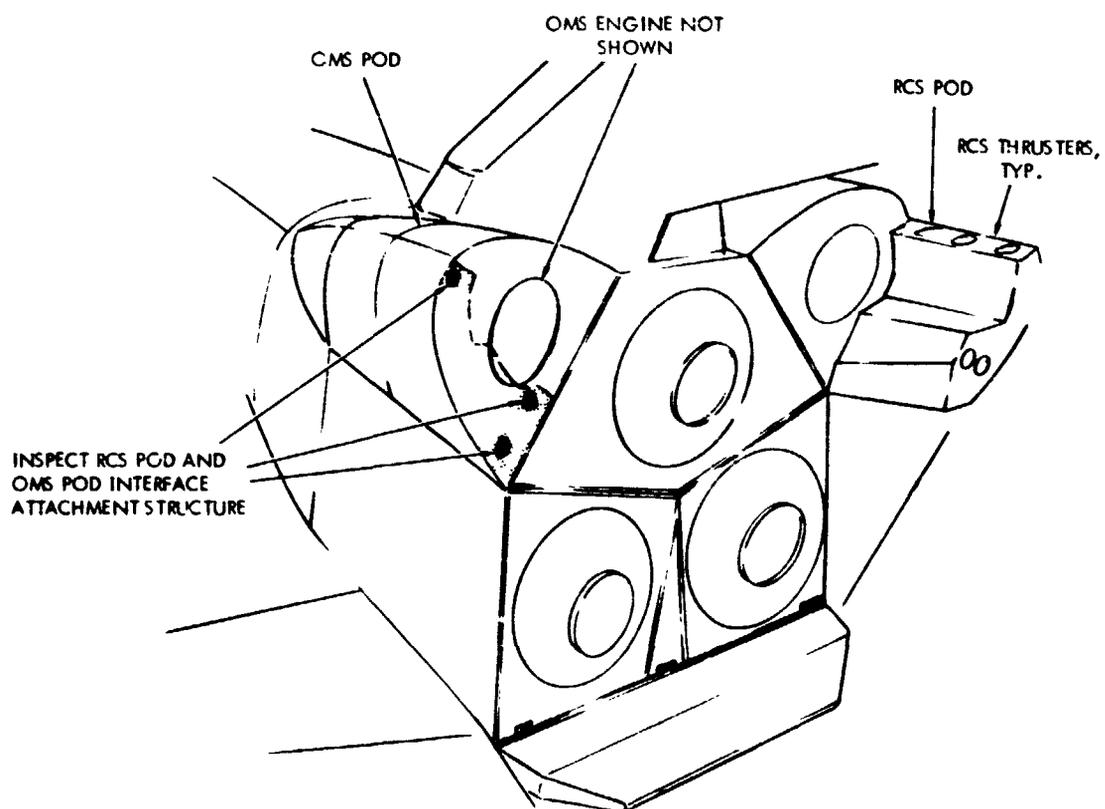
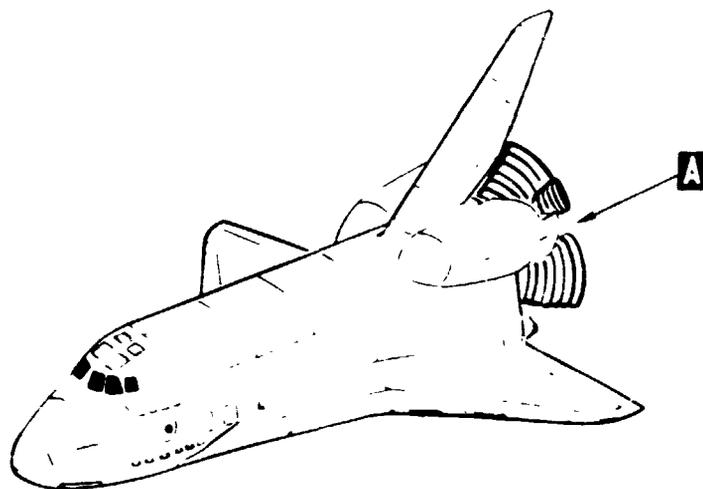
The RCS engine pod is attached to the OMS pod aft bulkhead frame structure at three points on each pod. Two of these are along the $Y_p = 100$ plane at $Z_p = 35$ and $Z_p = 67.8$, and the third attach point is at $Y_p = 135$ and $Z_p = 43.8$. The attach points receive and transfer RCS thruster loads to the OMS pod aft bulkhead support structure during orbital maneuvers. The material of construction is 2024 aluminum alloy.

DEFECTS: Cracks in the OMS pod/RCS pod attachment areas, particularly around the attachment bolt.

ACCESS: Access is from outside the fuselage to the right and left of main engine number 1.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C) and eddy current surface probe (para. 1.5.4.4)

Backup: Eddy current bolt hole (para. 1.5.4.3) and fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



A



OMS /RCS POD STRUCTURE - RCS-OMS POD ATTACHMENT
Figure 4-28. Aft RCS Pod Attach Structure

PROCEDURE NO. 4-529, Figure 4-29

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: RCS POD

DRAWING(S): VL72-000091

COMPONENT/AREA DESCRIPTION: AFT RCS ENGINE MOUNTS.

Each aft RCS pod attached to the aft bulkhead of the OMS pods contain 12 thruster engines for Orbiter attitude control during Orbital maneuvers and the RCS fuel tankage. The engine mounts hold the engines in their respective fixed rigid positions and receive the engine thrust loads. The fittings are made of aluminum alloy and have a zinc-chromate primer and Supercorapon paint surface finish.

DEFECTS: Cracks in the engine mount attachment holes.

ACCESS: Removable panels in the RCS shell structure permit access to the engine mounts. Access is from outside of the aft fuselage to the right and left of main engine number 1.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C) or eddy current surface probe (para. 1.5.4.4)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

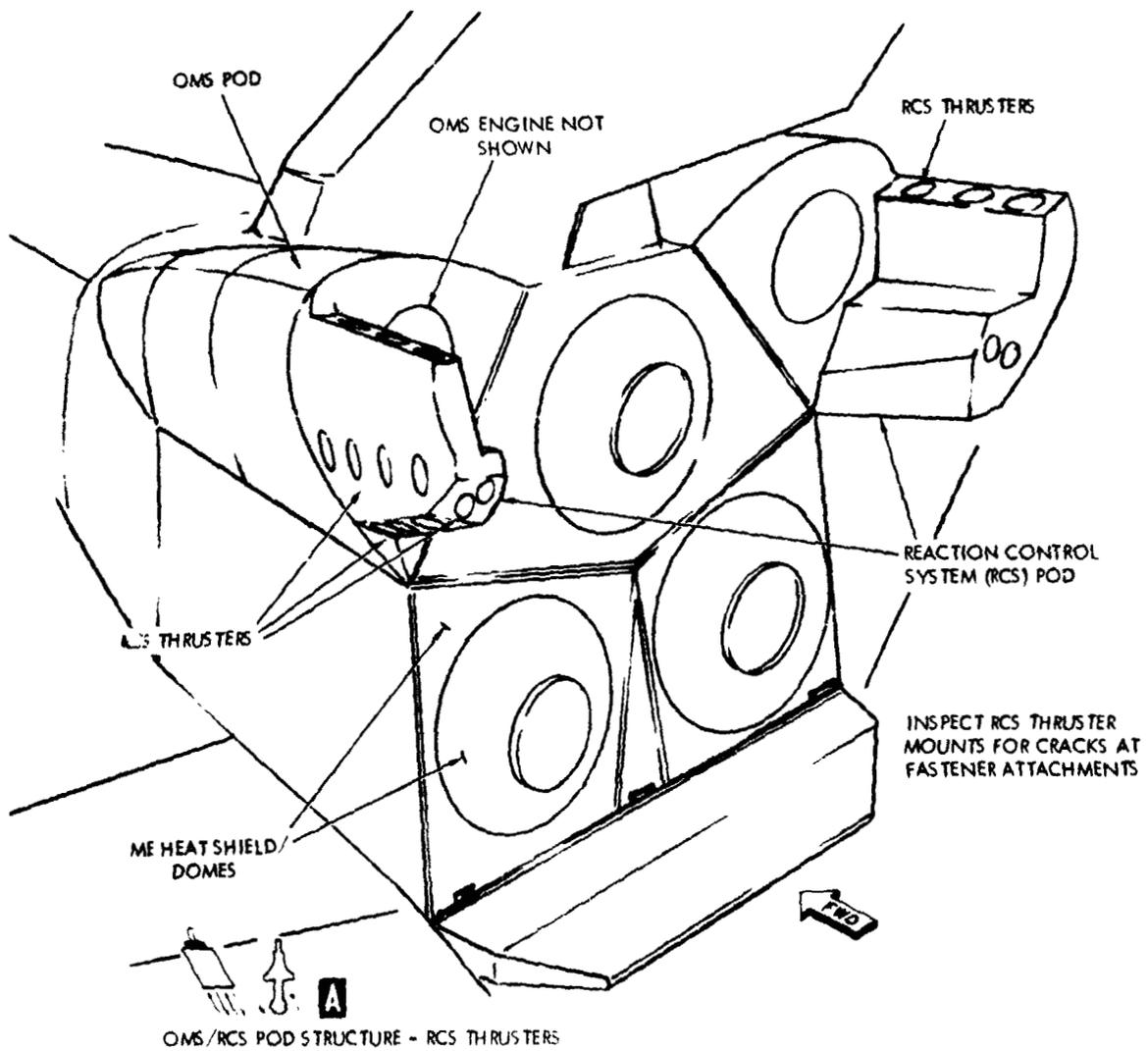
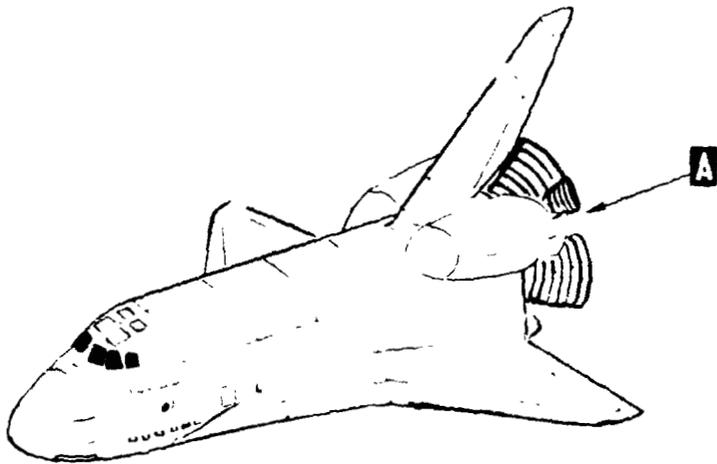


Figure 4-29. Aft RCS Engine Mounts

PROCEDURE NO. 4-530, Figure 4-30

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

TYPE INSPECTION

(X) POSTFLIGHT

SUBASSEMBLY: AFT BODY FLAP

DRAWING(S): VL70-355114, VL70-005105, VL70-355053

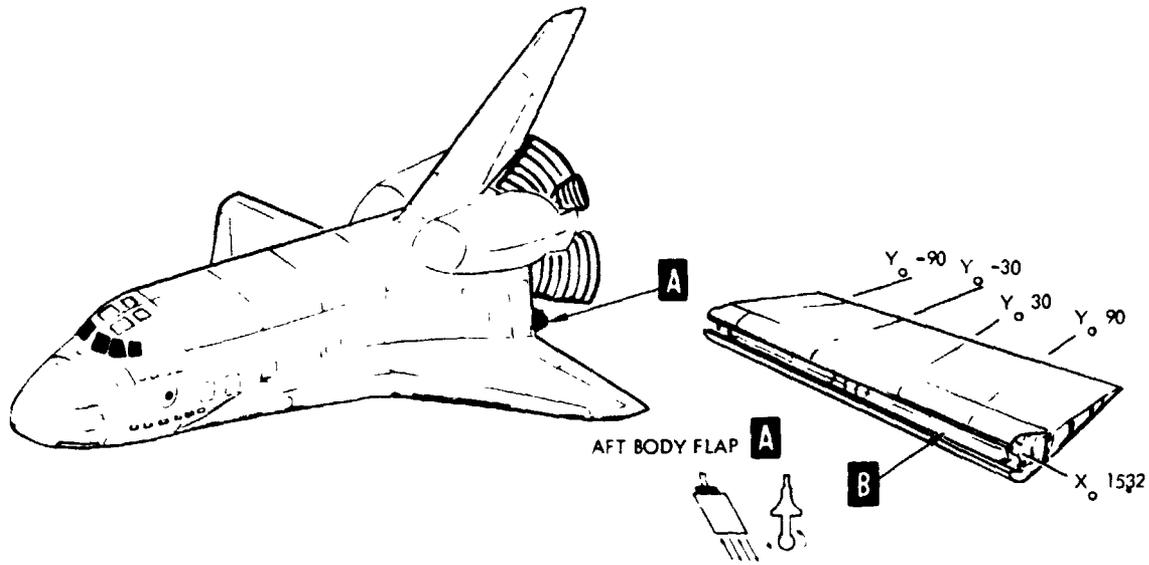
COMPONENT/AREA DESCRIPTION: AFT BODY FLAP HINGES. The aft body flap is used to protect the main engine skirts and to provide a movable control surface for vehicle trim during entry. It is actuated at four locations by power hinges at $Y_{\circ} \pm 30$ and $Y_{\circ} \pm 90$ along the X_{\circ} 1532 hinge line. The power hinges are attached to the body flap front spar and the lower aft-fuselage heat shield support frame. Aerodynamic loads during entry and atmospheric flight and high vibro-acoustic loads at lift-off may cause damage to the hinges. The hinges are made of titanium (-6Al-4V) alloy.

DEFECTS: Radial cracks at hinge assembly bolt holes and at hinge attachment arms.

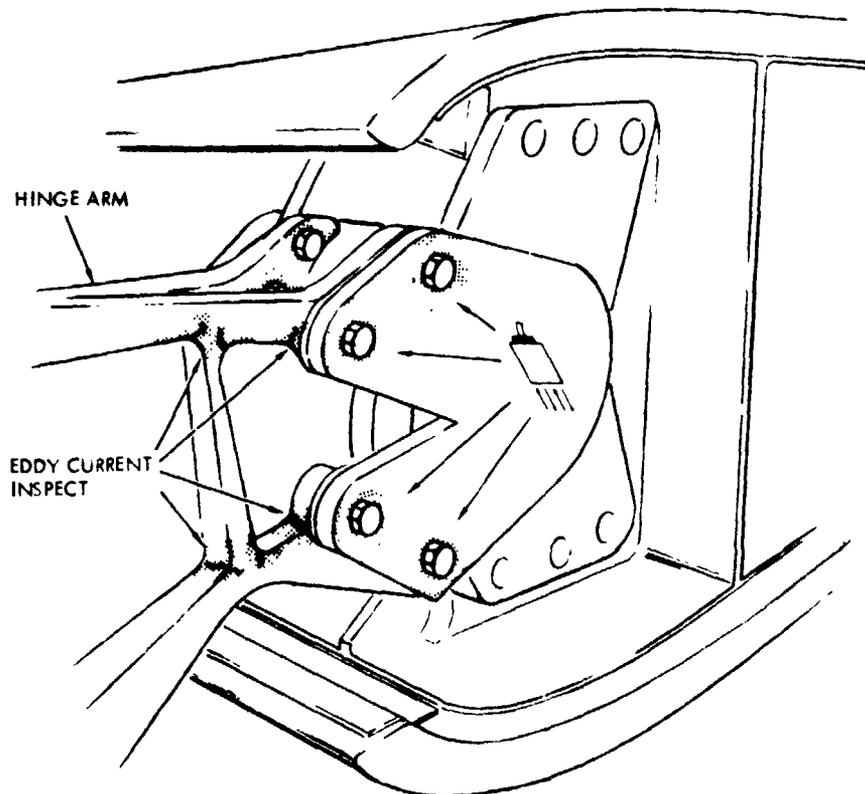
ACCESS: Remove flap hinge thermal seals and deploy flap full up or down as necessary.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B & C) for bolt holes; ultrasonic surface wave (para. 1.5.5.1) for attachment arms (if hinge is made of uncoated titanium) or eddy current surface probe (para. 1.5.4.4).

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).



ULTRASONIC INSPECT
AROUND BOLT HOLES
IN HINGE FITTINGS
AND HINGE ARM



B AFT BODY FLAP
HINGE FITTINGS,
TYPICAL 4 PLACES

Figure 4-30. Aft Body Flap Hinges

PROCEDURE NO. 4-531, Figure 4-31

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: BODY FLAP

DRAWING(S): VL70-355053, VL70-355114

COMPONENT/AREA DESCRIPTION: AFT BODY FLAP HINGE SPAR/RIB ATTACH.

The body flap front spar and rib flap hinge attachments are made of 2024-T86 aluminum alloy sheet. They have a zinc chromate primer and Supercorapon 515-700 finish. These ribs transfer power hinge loads into the body flap and react flap aerodynamic loads. Aerodynamic loads imposed on these attachment areas when the body flap is deployed during entry and high vibroacoustic loads during lift-off may produce damage at the attachment.

DEFECTS: Radial cracks originating in the attachment holes of the flap hinge rib and the hinge plate.

ACCESS: Remove the thermal seal and deploy the flap full up or down as necessary.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C) or eddy current surface probe (para. 1.5.4.4)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

PROCEDURE NO. 4-532, Figure 4-32

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: AFT BODY FLAP

DRAWING(S): VL70-355053, VL70-355114

COMPONENT/AREA DESCRIPTION: AFT BODY FLAP FRONT SPAR.

The front spar is made of 2024-T86 aluminum alloy and contains a zinc chromate primer and Supercorapon 515-700 paint surface finish. The body flap power hinges transfer loads into the front spar because of vibroacoustic loads and reactions to aerodynamic loads. The areas of the front spar in the vicinity of the hinges should be inspected for fatigue damage.

DEFECTS: Edge through-cracks in the spar caps and webs in the vicinity of body flap hinge attachments to hinge ribs.

ACCESS: Remove flap hinge thermal seals and deploy the body flap up or down as necessary.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4)
Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

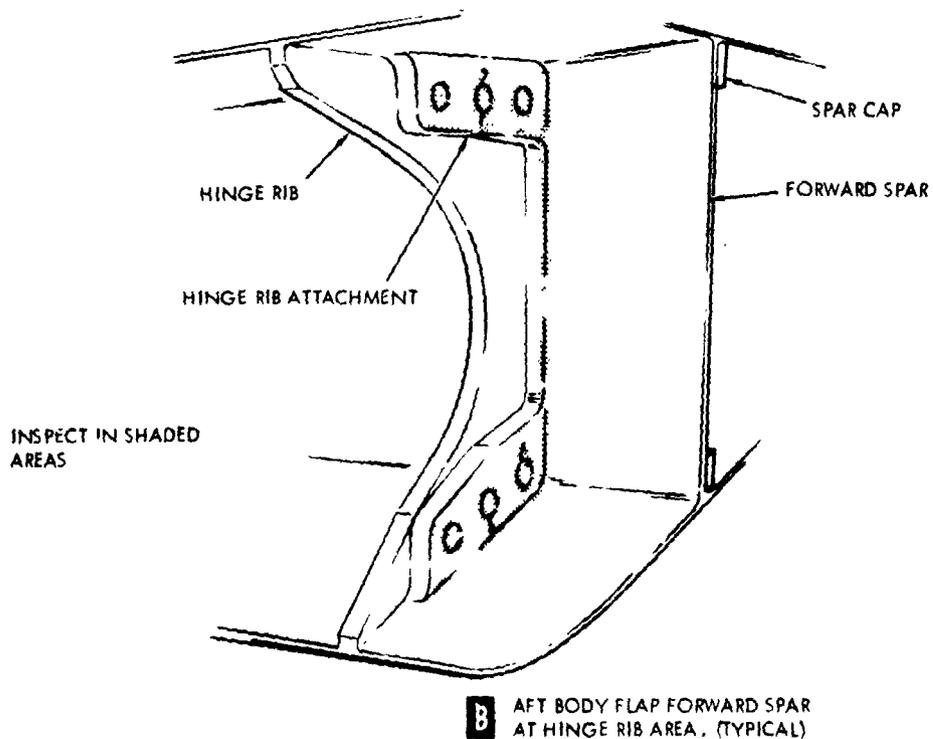
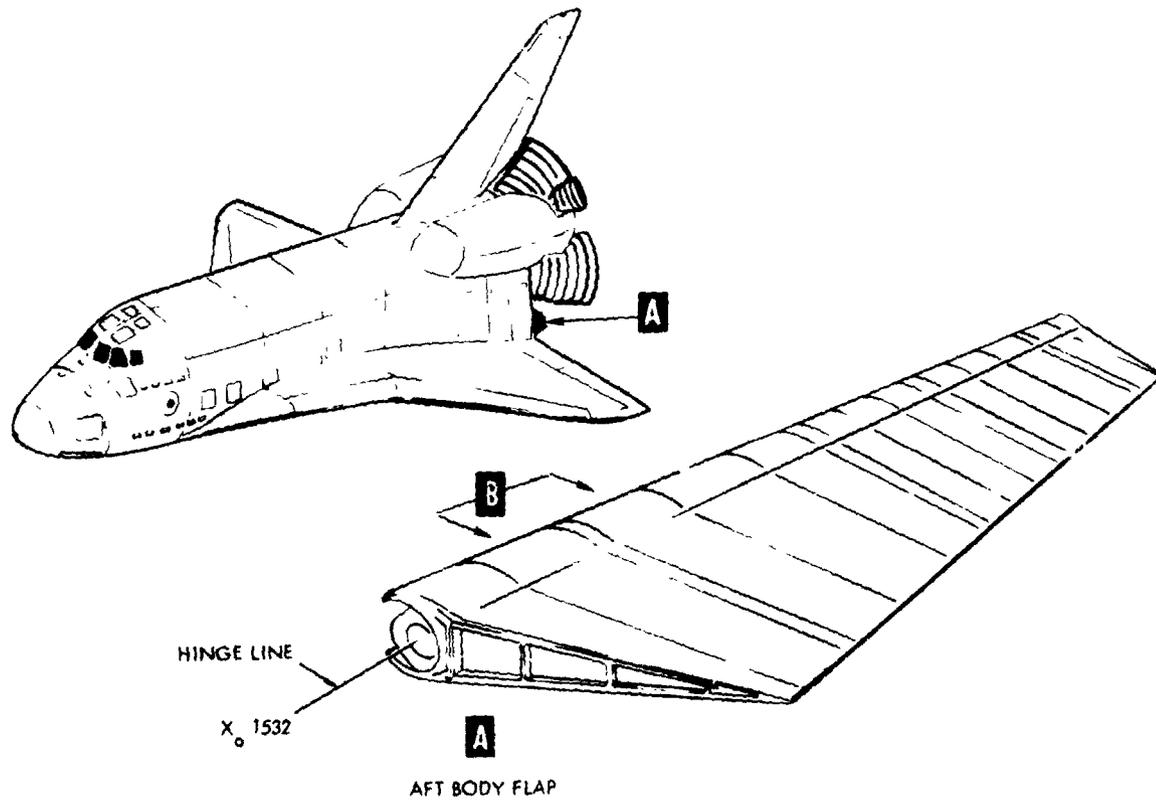


Figure 4-32. Aft Body Flap Front Spar

PROCEDURE NO. 4-533, Figure 4-33

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, AFT FUSELAGE,
ZONE 5

(X) POSTFLIGHT

SUBASSEMBLY: AFT BODY FLAP

DRAWING(S): VL72-000091, VL70-355114

COMPONENT/AREA DESCRIPTION: BODY FLAP HONEYCOMB SKIN PANELS.

The body flap is an aerodynamic control surface located along the entire length of the aft lower trailing edge at $X_o = 1528$, $Z_o = 278$. The structure of the body flap is TPS-protected aluminum honeycomb, consisting of upper and lower honeycomb panels, joined to a trailing edge full-depth honeycomb assembly. The face sheets are 2219-T851 (0.016-inch thick) and the core is 5052, H39 aluminum alloy.

The flap is used to protect the main engine skirts and to provide a movable control surface for vehicle trim during entry. The assembly is subjected to vibroacoustic, aerodynamic and thermomechanical loads which may cause face sheet to core disbands or core separations near the bondline. Core damage due to ice or corrosion caused by internal residual reactive gases and moisture can also occur with time and repeated mission cycles. Core damage on lower surface may be caused by impact of runway debris.

DEFECTS: Inspect for core-to-facesheet or near-bondline disbands and separations, entrapped water, and core damage corrosion (crushed core and corrosion).

ACCESS: Access is readily attained. To inspect for disbands, the TPS materials must be removed. Not necessary to remove TPS for water entrapment or core damage inspection.

NDT TECHNIQUES: Primary: Sonic (para. 1.5.5.6) or thermographic (para. 1.5.8.2) technique for disbands/separations; X-ray (para. 1.5.6.2) for water entrapment and core damage (image enhancement of radiographs recommended since TPS will attenuate contrast).

**ORBITER, AFT FUSELAGE, ZONE 5
AFT BODY FLAP**

NDT TECHNIQUES: Backup: For disbond verification, use a mechanical pull test on local suspect area. Core damage can be verified by ultrasonic or sonic (para. 1.5.5.6) thru-transmission techniques.

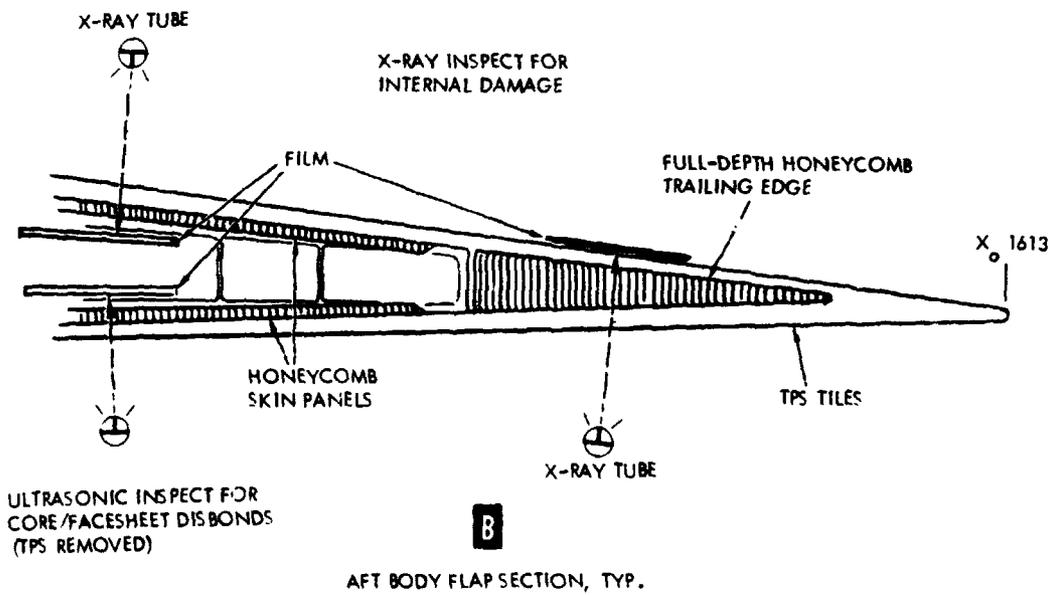
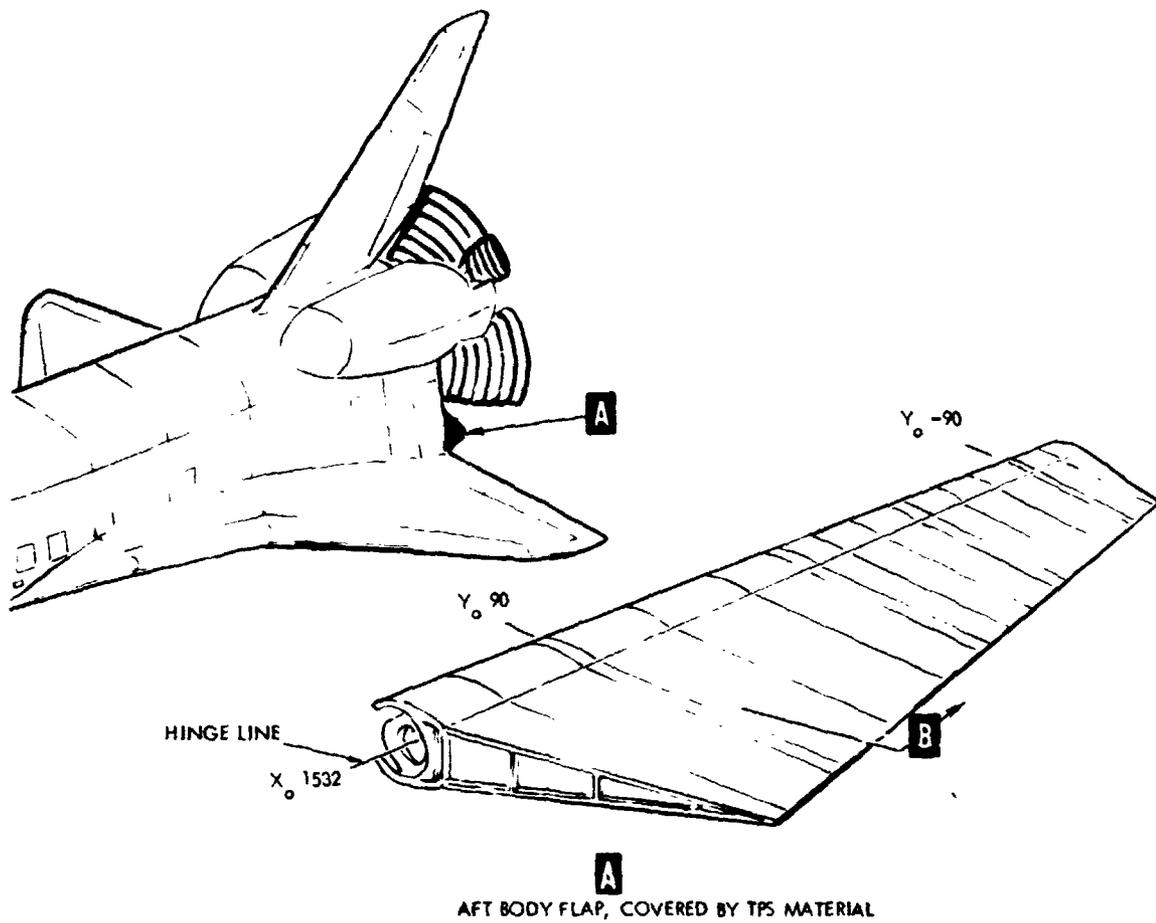


Figure 4-33. Aft Body Flap Honeycomb Skin Panels

SECTION 5. WING STRUCTURE

This section contains the NDE requirements for the wing box spars, ribs and skin, the main landing gear and wheel well, wing fuselage interface, and the elevons.

SECTION 5
TABLE OF CONTENTS

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
5-601	MLG Drag Link Support Fitting	5-1
5-602	MLG Main Trunnion Support Fitting	5-3
5-603	MLG Main Strut Uplock Support Beam	5-5
5-604	Clevis Attach Fittings, Wing-to-Fuselage	5-7
5-605	Wing Lower Wing/Fuselage Tension Tie	5-9
5-606	MLG Box Forward Spar	5-11
5-607	MLG Box Outer Rib, Upper and Lower Intersections with Wing	5-13
5-608	MLG Box Aft Spar Caps	5-15
5-609	MLG Axle	5-17
5-610	MLG Cross Tube	5-18
5-611	MLG Shock Strut Piston	5-19
5-612	MLG Main Cylinder	5-20
5-613	MLG Torque Arm	5-21
5-614	MLG Lower Lock Brace	5-22
5-615	MLG Upper Lock Brace	5-23
5-616	MLG Lower Drag Brace	5-24
5-617	MLG Upper Drag Brace	5-24
5-618	Leading Edge Spar Caps at Wing Rib/Spar Attachments and L.E. Attach Brackets	5-27
5-619	Wing Lower Skin Panels	5-29
5-620	Wing Spar Caps	5-32
5-621	Wing Rib Caps	5-35
5-622	Wing Spar/Rib Splices	5-38
5-623	Elevon Actuator Attach Fittings	5-41
5-624	Elevon Hinges	5-43
5-625	Elevon Honeycomb Skin Panels	5-45
5-626	Elevon Web Stiffeners	5-47

SECTION 5
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
5-1	MLG Drag Link Support	5-2
5-2	MLG Trunnion Support Fitting	5-4
5-3	MLG Main Strut Uplock Support Beam	5-6
5-4	Clevis Attach Fittings, Wing-to-Fuselage	5-8
5-5	Wing Lower Wing/Fuselage Tension Tie	5-10
5-6	MLG Box Forward Spar	5-12
5-7	MLG Outer Rib-to-Wing Structure, Upper and Lower Attach	5-14
5-8	MLG Box Aft Spar Caps	5-16
5-9	Main Landing Gear Assembly	5-26
5-10	Leading Edge Spar Caps	5-28
5-11	Wing Lower Skin Panels	5-30
5-12	Wing Spar Caps	5-33
5-13	Wing Rib Caps	5-36
5-14	Wing Spar/Rib Splices	5-39
5-15	Elevon Actuator Attach Fittings	5-42
5-16	Elevon Hinges	5-44
5-17	Elevon Honeycomb Skin Panels	5-46
5-18	Elevon Web Stiffeners	5-48

PROCEDURE NO. 5-601, Figure 5-1

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: MLG WELL

DRAWING(S): VL72-000091, GRUMMAN B91B00001
AND 70Z1046

COMPONENT/AREA DESCRIPTION: MLG DRAG LINK SUPPORT FITTING.

There are two trunnion fittings in each MLG wheel well for attaching the drag link into the airframe structure. The outboard fitting is accommodated by the wheel well wing rib and the inboard fitting by the mid-fus outer structure. These fittings are located at $X_o \pm 1100$, $Y_o \pm 107$, and ± 167 , $Z_o \pm 317$. They are machined from 2124-T851 aluminum alloy plate and are finished with an abrasion-resistant polyurethane enamel. The adjacent wing rib and fuselage structure are made of 2024 aluminum alloy. The fittings receive and distribute high bending loads during landing touchdown, rollout, turning and taxi.

DEFECTS: Hard landings and taxi conditions may produce radial fatigue cracks around the bearing housing bolt holes and fillets in the bearing housing and the bearing housing support fitting and at fastener holes in attachments to adjacent wing rib or fuselage structure, including the bootstrap fittings.

ACCESS: Mainly, inspection is from inside wheel well; additional inspection of support beam: inboard side of inboard fittings can be inspected from inside the mid-fus underfloor space by entering the MLG well-fuselage access opening; outboard side of outboard fittings can be inspected by entering outboard wing box area through the wing-fuselage access opening. Remove bolts and/or enamel for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B & C) for bearing hole inspection, eddy current (para. 1.5.4.4) for fillet areas and bootstrap fittings.

Backup: Eddy current bolt hole (para. 1.5.4.3) for bolt holes and fluorescent penetrant (para. 1.5.2.1 Fig. 1-9) for other areas.

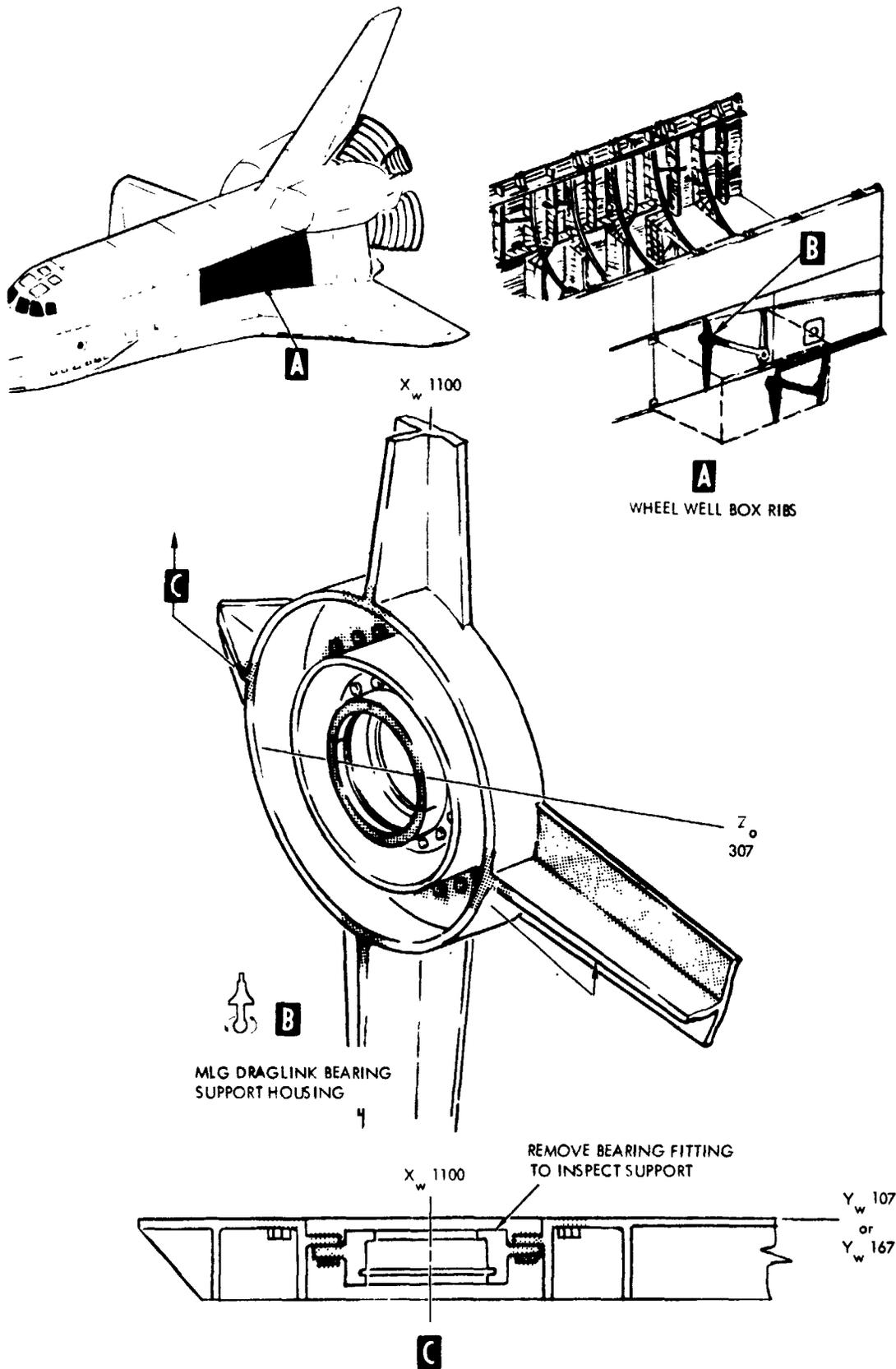


Figure 5-1. MLG Drag Link Support

PROCEDURE NO. 5-602, Figure 5-2

<u>MAJOR ASSEMBLY:</u>	ORBITER, WING, ZONE 6	<u>TYPE INSPECTION</u>
<u>SUBASSEMBLY:</u>	MLG BOX	(X) POSTFLIGHT
<u>DRAWING(S):</u>	VL72-000091 CRUMMAN B91B00001 AND 70Z1046	

COMPONENT/AREA DESCRIPTION: MLG MAIN TRUNNION SUPPORT

FITTING. There are two fittings, inboard and outboard, for attaching the main trunnion fittings into the airframe structure in each wheel well and containment of the trunnion bearing. The outboard fitting is accommodated by the wheel well rib and the inboard fitting by the mid-fus outer structure. These fittings are located at $X_{\circ} 1180$, $Y_{\circ} \pm 107$ and ± 167 , $Z_{\circ} 283$. The fittings are machined from 2124-T851 aluminum alloy plate and are finished with an abrasion-resistant polyurethane enamel. The adjacent wing rib and fuselage structure are 2024 aluminum alloy. The fittings receive and distribute high bending loads during landing touchdown, rollout, turning and taxi.

DEFECTS: Hard landings and taxi conditions may produce radial fatigue cracks at the bearing housing bolt-hole and fillets in the bearing housing and in the bearing housing support fitting; cracks at attachment holes in the boot-strap fitting.

ACCESS: Mainly, inspection is performed from inside MLG wheel well; additional inspection of support beam inboard side of inboard fittings can be inspected from inside the mid-fus underfloor space by entering the MLG well-fuselage access opening and outboard side of outboard fittings can be inspected by entering outboard wing box area. Remove bolt and/or enamel for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B & C) for bolt holes, eddy current (para. 1.5.4.4) for fillet areas and bootstrap fitting.

Backup: Eddy current bolt-hole (para. 1.5.4.3) for bolt-holes
fluorescent penetrant (para. 1.5.2.1 Fig. 1-9) for fillets and other areas.

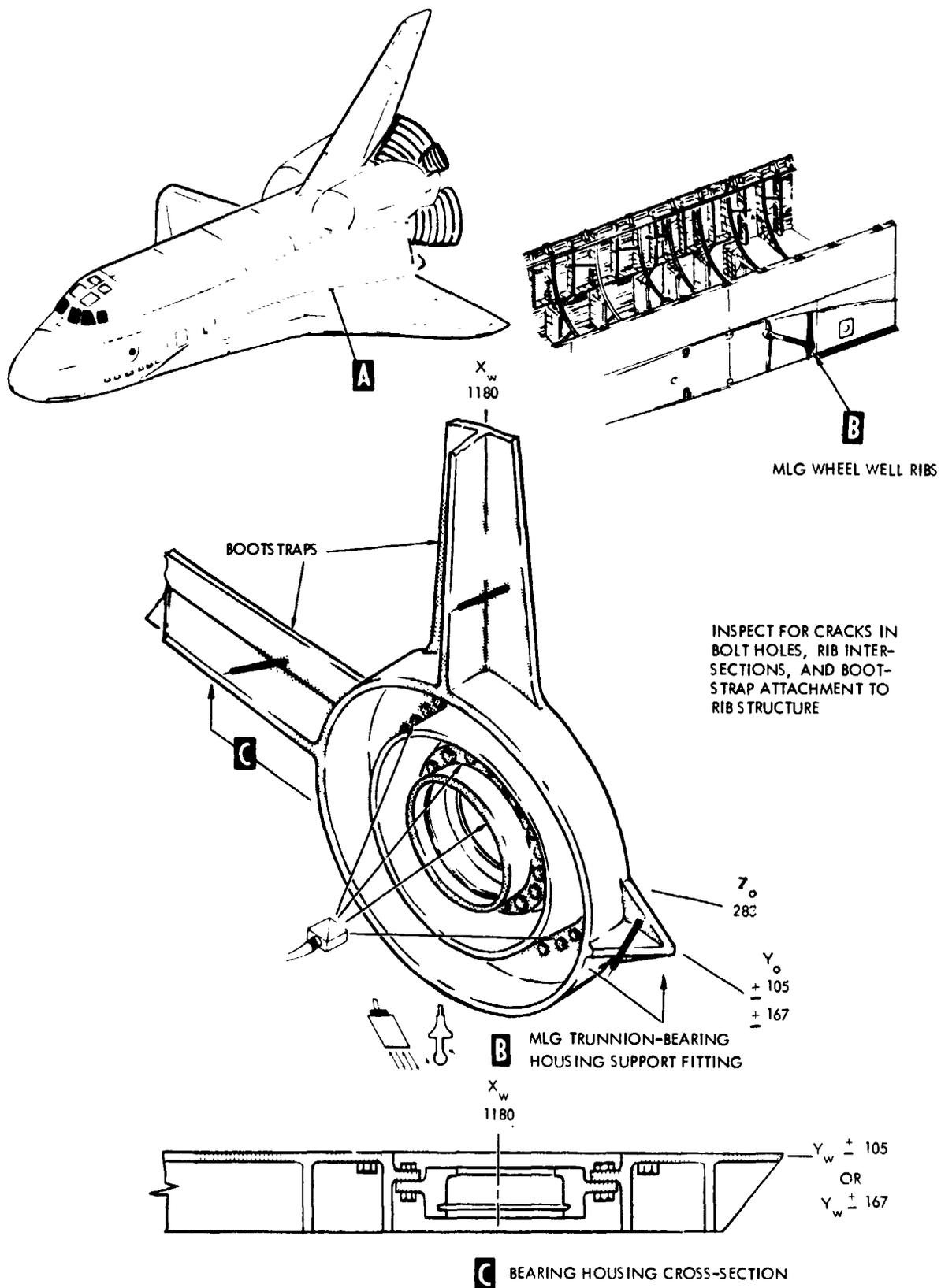


Figure 5-2. MLG Trunnion Support Fitting

PROCEDURE NO. 5-603, Figure 5-3

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: MAIN LANDING GEAR BOX

(X) POSTFLIGHT

DRAWING(S): VL72-000091, GRUMMAN B91B00001

COMPONENT/AREA DESCRIPTION: MLG MAIN STRUT UPLOCK

SUPPORT BEAM: The spanwise beam is at X_o 1108 and Z_o 325 in the upper surface of the MLG box and contains a strut up-lock fitting. This structure provides the means to lock and support the MLG in the full up position during ascent, orbiting, entry, cross-range and cruise flight. In supporting the MLG in this position the fitting and beam are subject to G-loads, vibrations and shock loads. The structure is made of 2024 aluminum alloy and finished with an abrasion-resistant polyurethane enamel. The fitting is probably a 300M steel machining.

DEFECTS: Fatigue cracks may occur in the root area where the fitting joins the support beam, also where the beam reinforcements tie into the wing upper skin.

ACCESS: These areas are accessible from inside the MLG well with the LG fully extended. It will be necessary to remove the local finish to perform the backup inspection.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4) for areas on up-lock support beam and fitting.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

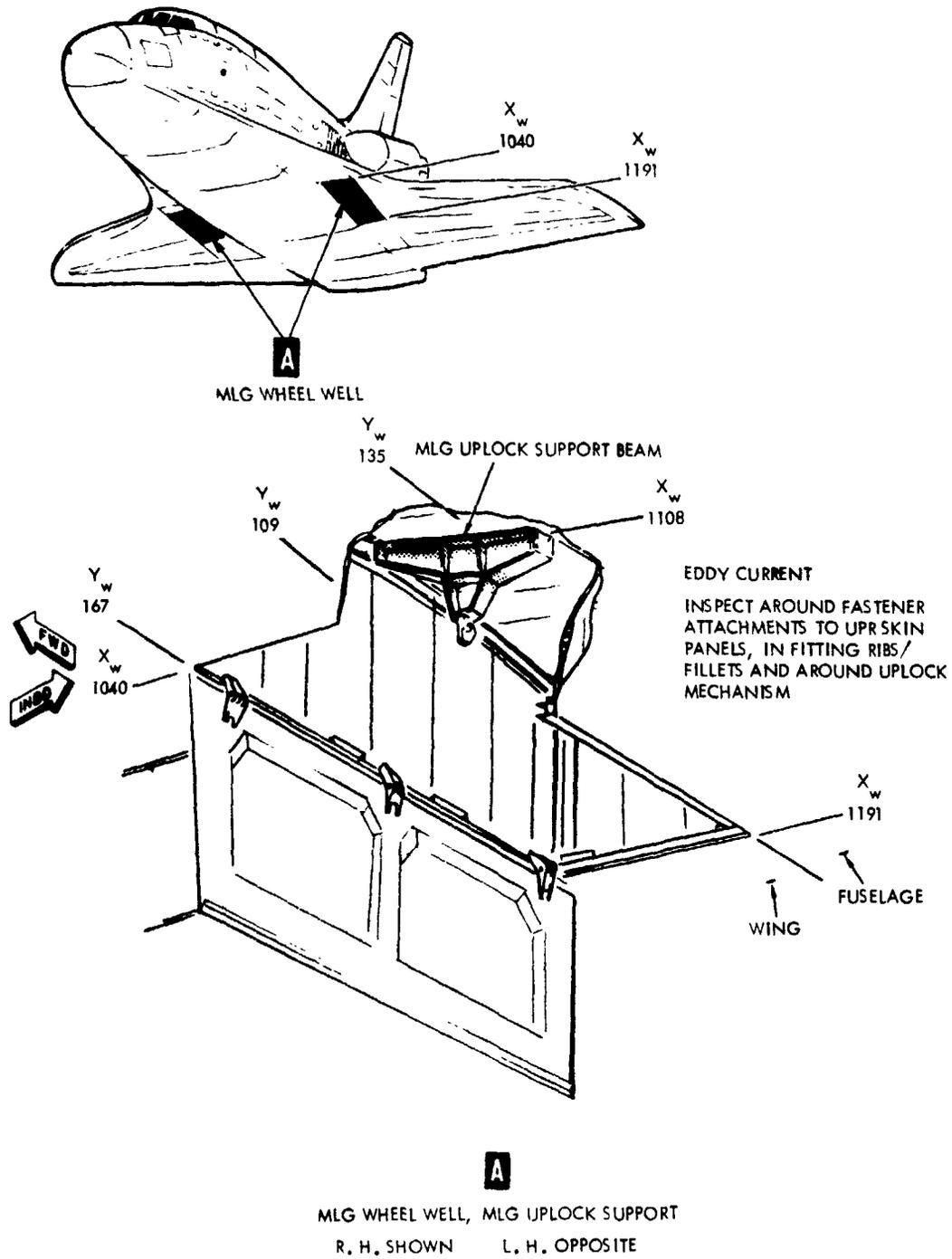


Figure 5-3. MLG Main Strut Uplock Support Beam

PROCEDURE NO. 5-604, Figure 5-4

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: WING-FUSELAGE INTERFACE

DRAWING(S): GRUMMAN B91B00001

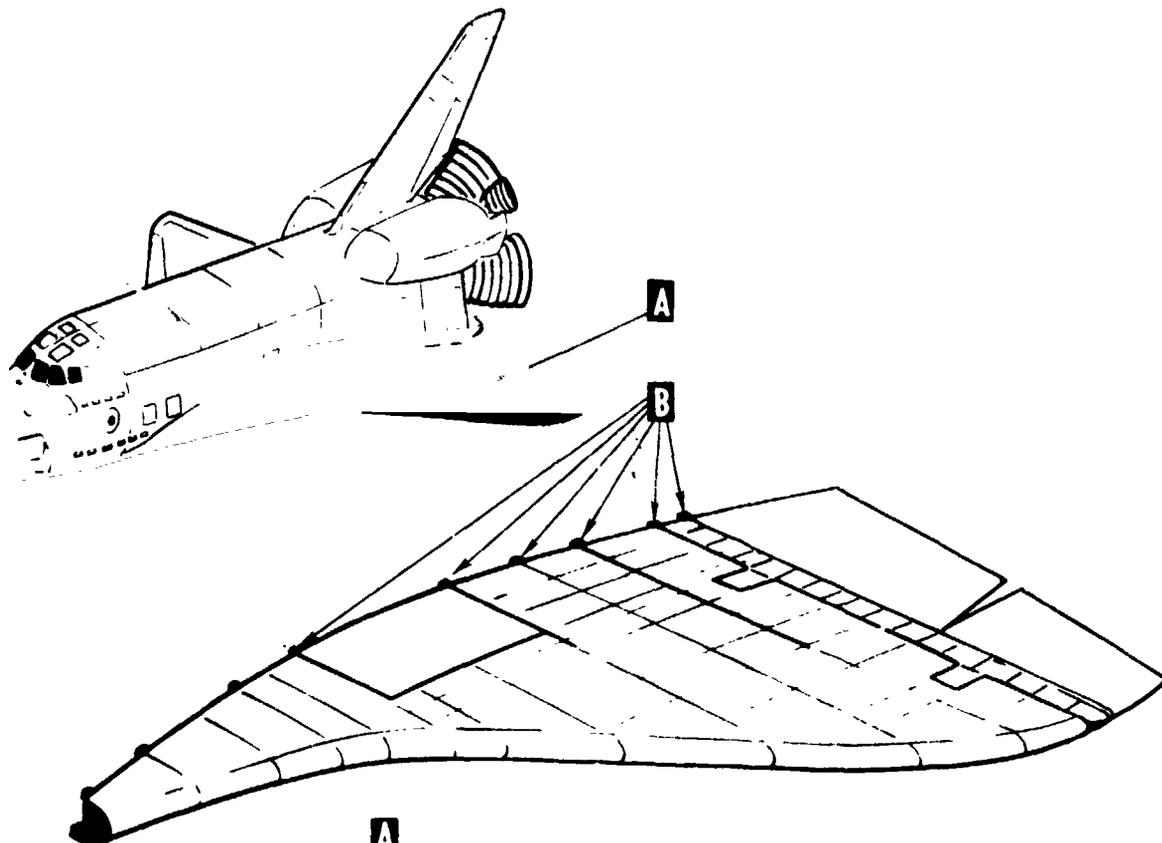
COMPONENT/AREA DESCRIPTION: CLEVIS ATTACH FITTINGS, WING-TO-FUSELAGE. Located at $Y_{\circ} \pm 109$, $X_{\circ} 789, 901, 973, 1047, 1191, 1249, 1307$, and $Y_{\circ} 121$, $Z_{\circ} 298$. Five attachments are located along the $Z_{\circ} 315$ and five are located between $Z_{\circ} 272$ and $Z_{\circ} 284$ along the lower wing-to-fuselage mold line (10 attachments each wing). The safelife fittings receive high tension or shear loads during high-Q boost and compressive/tensile loads during atmospheric flight and landing. These 2124-T851 aluminum alloy machined plate fittings are typically multi-lug configurations mating with a single-lug fitting. One set of lugs are part of the wing structure and the mating lugs are in the mid-fuselage structure. Each attachment is held intact by a bolt inserted through the mated lugs.

DEFECTS: Fatigue cracks can occur in the bolt holes, upper and lower edge of hole; in forward and aft fittings, cracks may also occur in lug fillet where lug blends into base (on fuselage).

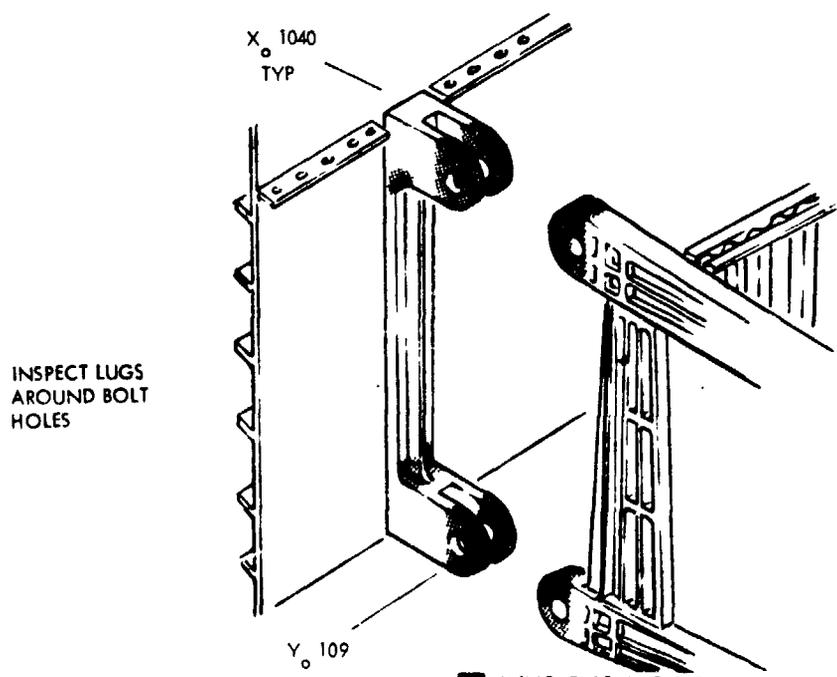
ACCESS: Access to the clevis attachments is gained by entering the wing box through access manholes fore and aft of the MLG well, also from inside the MLG well ($X_{\circ} 1047$ and 1191 location). Primary inspection is performed with bolts in place. Remove bolt for backup inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) and eddy current surface probe (para. 1.5.4.4)

Backup: Eddy current bolt hole (para. 1.5.4.3) for clevis bolt holes, fluorescent penetrant (para. 1.5.2.1 Fig. 1-9) for other areas.



A
WING-WING/FUSELAGE INTERFACE



B WING-FUSELAGE CLEVIS ATTACH FITTINGS

Figure 5-4. Clevis Attach Fittings, Wing-to-Fuselage

PROCEDURE NO. 5-605, Figure 5-5

<u>MAJOR ASSEMBLY:</u>	ORBITER, WING, ZONE 6	<u>TYPE INSPECTION</u>
<u>SUBASSEMBLY:</u>	WING/FUSELAGE INTERFACE	(X) POST-LIGHT
<u>DRAWING(S):</u>	Fig. 1.4.4 of 73MA5769, GRUMMAN B91B00001	

COMPONENT/AREA DESCRIPTION: WING LOWER WING/FUSELAGE

TENSION TIE. Located along outboard ($Y_{\circ} \pm 105$) lower wing-to-fuselage attachment interface are 72 tension bolts between fuselage stations $X_{\circ} 1191$ and $X_{\circ} 1307$. Two tension bolts are installed in each of 36 riser bays on each side of the fuselage. The wing interface structure is made of 2024 aluminum alloy, finished with zinc chromate primer and Supercorapon 515-700 paint. The splice provides a hardpoint wing attachment to the fuselage lower aft longeron. Tension/compression load spectra are transferred through the structural tie point during all flight regimes. (NOTE: Coordinate this inspection with inspection of fuselage tension fittings).

DEFECTS: Fatigue cracks may occur in the tension bolt holes in the base of the fitting.

ACCESS: Enter the main wing box aft of the MLG well through the wing/fuselage access opening. For backup inspection, the tension bolt must be removed. (NOTE: Remove tension bolts only in accordance with engineering concurrence and applicable service manuals).

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 C)
Backup: Eddy current bolt-hole (para. 1.5.4.3)

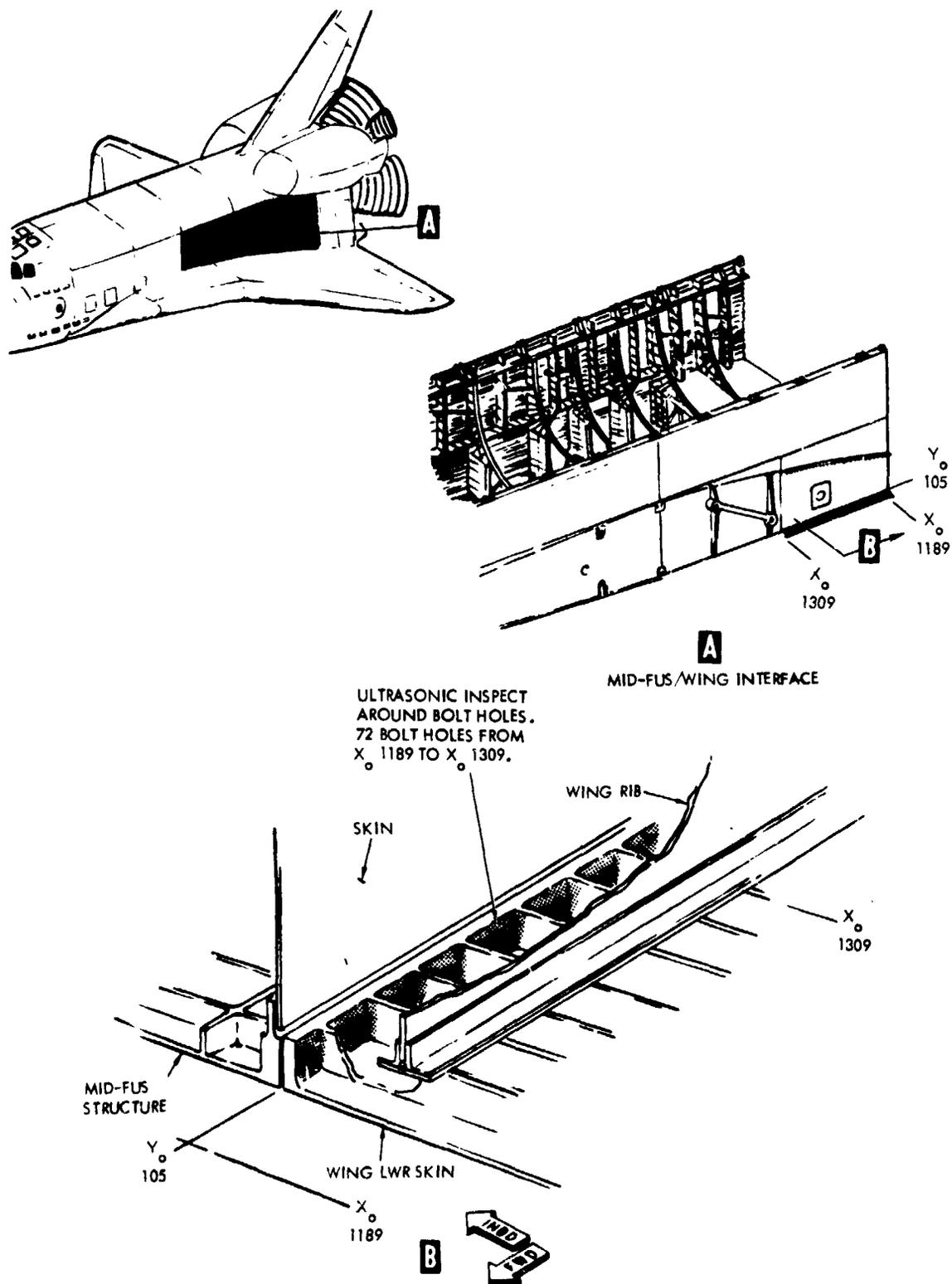


Figure 5-5. Wing Lower Wing/Fuselage Tension Tie

PROCEDURE NO. 5-606, Figure 5-6

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: MAIN LANDING GEAR BOX

(X) POSTFLIGHT

DRAWING(S): VL72-000091, GRUMMAN B91B00001

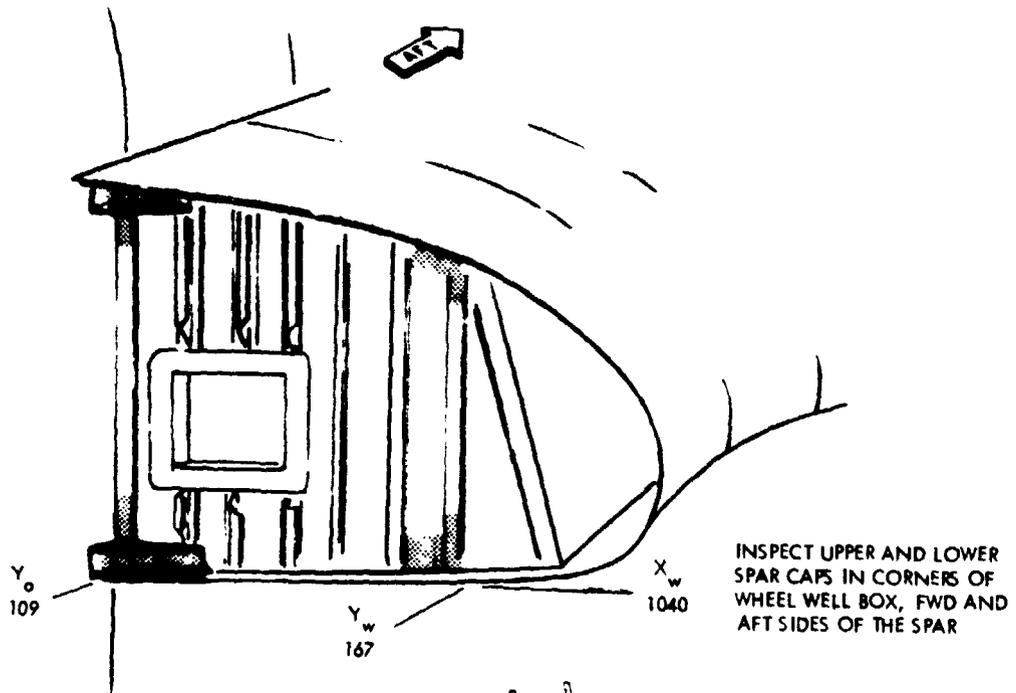
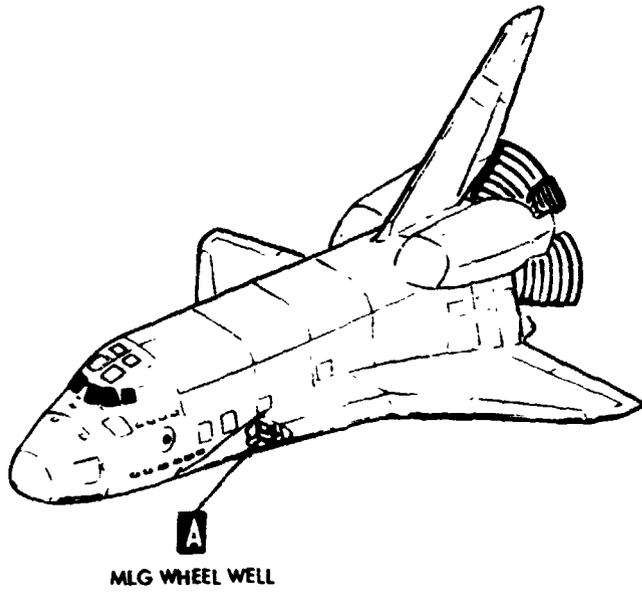
COMPONENT/AREA DESCRIPTION: MLG BOX FORWARD SPAR. The components of this spar are 2024 aluminum alloy with an abrasion-resistant polyurethane enamel surface finish within the MLG box. The spar is located at $X_{\circ} 1040$ and forms the forward wall of the box. It attaches to the mid-fuselage structure at $Y_{\circ} \pm 105$ through moment ties, to the MLG box outboard rib at $Y_{\circ} 167$ and to upper and lower wing skin panels. The spar caps (upper and lower) in the vicinity of these attachments should be inspected for fatigue damage induced by wing flight loads, landing and taxi loads.

DEFECTS: Radial cracks in spar cap attachment holes and edge cracks near the fuselage and outer MLG box rib attachments.

ACCESS: Access is from inside the MLG box with the MLG fully extended. The portion of the spar forward of the box is reached by entering wing box forward of the MLG box through the whole body access opening in the spar. Backup inspection will require stripping of paint.

NDT TECHNIQUES: Primary: Eddy current (para. 1.5.4.4) and or ultrasonic shear wave (para. 1.5.5.3 C)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



MLG WHEEL WELL FORWARD SPAR (FWD SIDE) AT X_w 1040
 L.H. SHOWN R.H. OPPOSITE



Figure 5-6. MLG Box Forward Spar

PROCEDURE NO. 5-607, Figure 5-7

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: MLG BOX

DRAWING(S): VL72-000091, GRUMMAN B91B00001

COMPONENT/AREA DESCRIPTION: MLG BOX OUTER RIB-TO-WING

STRUCTURE UPPER AND LOWER INTERSECTIONS:

The stiffened outer rib, of 2024 aluminum alloy, attachments directly above the MLG main trunnion and at fore and aft corners of the MLG box transfer load into the upper wing panels during landing, rollout and taxi. A similar situation exists where the rib attaches to the lower wing surface. The rib on the interior of the MLG box has an abrasion-resistant polyurethane enamel surface finish and on the outboard side the rib has a zinc chromate primer and Supercorapon 515-700 paint surface finish.

DEFECTS: Fatigue and overstress cracks can occur around fastener holes in the rib cap to wing panel stiffener area.

ACCESS: Access is from inside the MLG box with MLG fully extended and from inside the forward wing box. The forward wing box outboard of the MLG wheel box can be entered by way of the mid-fuselage-to-wing access opening.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4) and/or ultrasonic shear wave (para. 1.5.5.3 C)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. i-9)

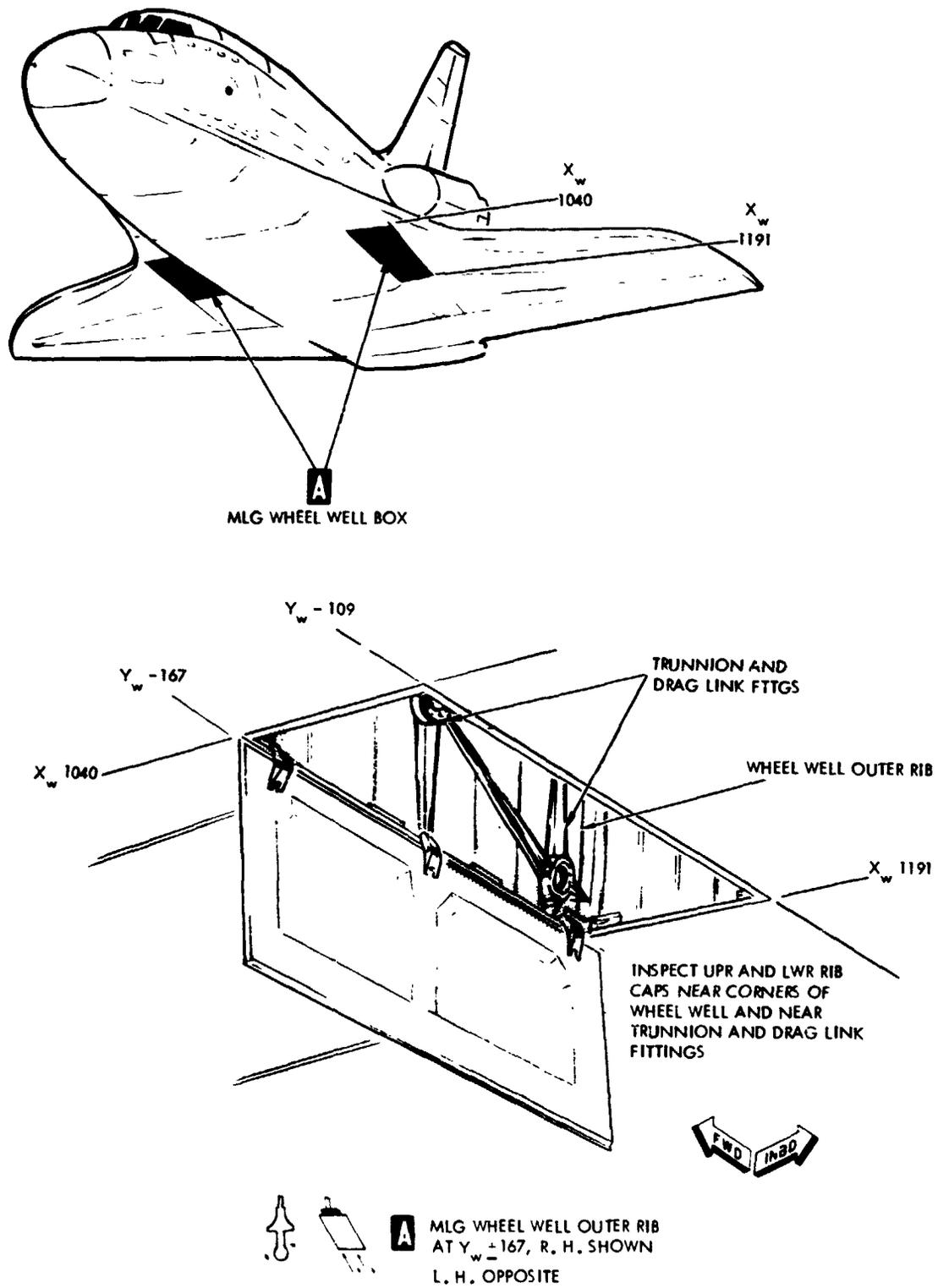


Figure 5-7. MLG Outer Rib-to-Wing Structure, Upper and Lower Attach

PROCEDURE NO. 5-608, Figure 5-8

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6 TYPE INSPECTION
SUBASSEMBLY: MAIN LANDING GEAR BOX (X) POSTFLIGHT
DRAWING(S): VL72-00091 GRUMMAN B91B00001

COMPONENT/AREA DESCRIPTION: MLG BOX AFT SPAR CAPS. The components of this spar are 2024 aluminum alloy with an abrasion-resistant polyurethane enamel surface finish within the box. The spar, located at $X_{\circ} 1191$, forms the aft wall of the MLG box and attaches to the mid-fuselage structure at $Y_{\circ} \pm 105$, to the MLG box outboard rib at $Y_{\circ} \pm 167$, and to the upper and lower wing panel. It is also a portion of the wing front beam. The upper and lower spar caps in the vicinity of these attachments may become damaged due to wing flight loads, landing and taxi loads and debris kicked up by the landing gear.

DEFECTS: Radial cracks in spar cap attachment holes and edge cracks near the fuselage and outer MLG box rib attachments.

ACCESS: Access is from inside the MLG box with the MLG fully extended. The portion of the cap aft of the box is reached by entering the main wing box through the fuselage-to-wing access opening. Backup inspection will require paint stripping.

NDT TECHNIQUES: Primary: Eddy current (para. 1.5.4.4) and/or ultrasonic shear wave (para. 1.5.5.3 C)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

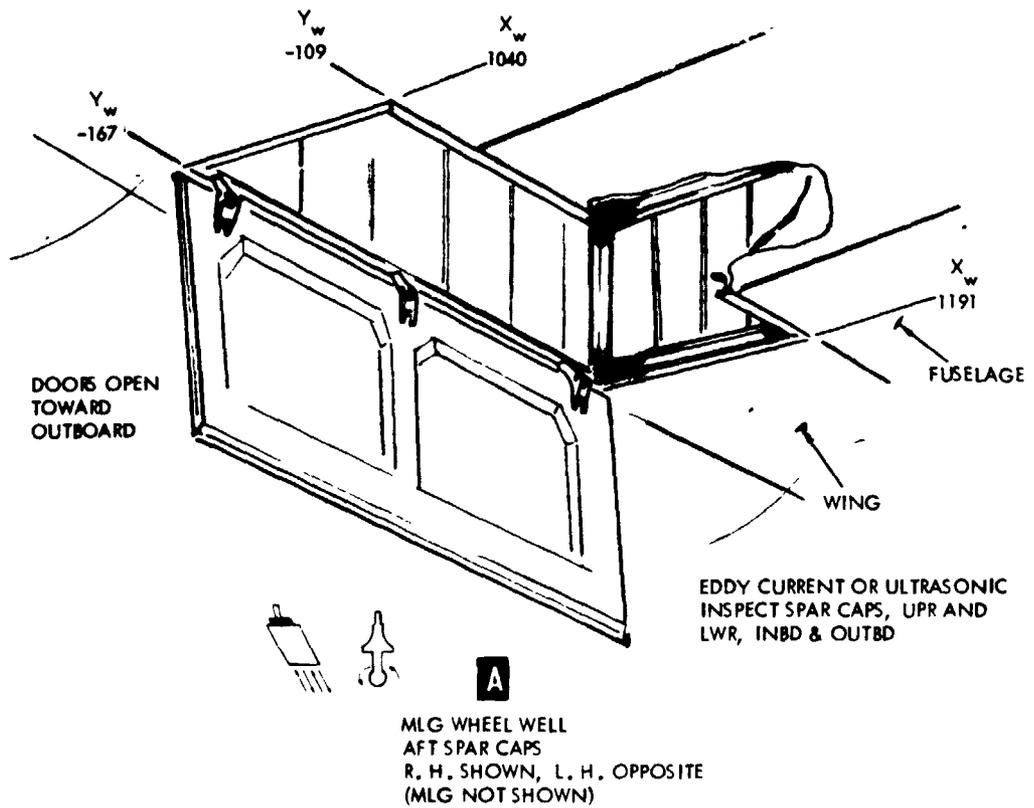
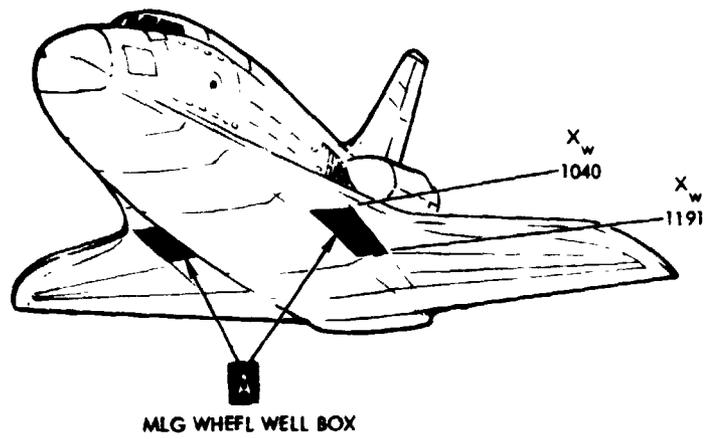


Figure 5-8. MLG Box Aft Spar Caps

PROCEDURE NO. 5-609, Figure 5-9

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: MAIN LANDING GEAR

(X) POSTFLIGHT

DRAWING(S): VL72-000103A & 73MA5769
(Figs. 1.6.1/1.9.1)

COMPONENT/AREA DESCRIPTION: MLG AXLE. This component is machined from a 300M steel forging and has a (TBD) surface finish. The axle is subject to bending and shear loads during taxi turns and adverse landing conditions. Damage may occur to the splines or to the body of the axle. One per MLG.

DEFECTS: Cracked splines and circumferential cracks in the middle portion of the axle body.

ACCESS: MLG fully extended and axle removed from the MLG cross tube. Backup inspection may require stripping of plating if present.

NDT TECHNIQUES: Primary: Magnetic particle (para. 1.5.3.2 circ.)
Backup: Fluorescent penetrant in spline areas (para. 1.5.2.1 Fig. 1-9)

PROCEDURE NO. 5-610, Figure 5-9

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: MAIN LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Figs. 1.9.1/1.6.1)

COMPONENT/AREA DESCRIPTION: MLG CROSS TUBE. This cylindrical fitting is made of a 300M forging and has an abrasion-resistant polyurethane enamel surface finish. It houses the MLG axle and mates to the MLG piston. It is subject to tensile loads during reverse braking and shear loads during MLG retraction. This safe-life designed component may accumulate damage during landing and taxi or because of residual intrinsic or build-up stresses combined with a salt-laden atmosphere. One per MLG.

DEFECTS: Circumferential cracks near piston interface, longitudinal cracks near end, and longitudinal stress-corrosion cracks along forging parting plane.

ACCESS: MLG fully extended and wheels removed. Removal from piston assembly may be necessary for inspection of mid-portion of tube.

NDT TECHNIQUES: Primary: Magnetic particle (para. 1.5.3.2 long.)
Backup: None required

PROCEDURE NO. 5-611, Figure 5-9

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: MAIN LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.1)

COMPONENTS/AREA DESCRIPTION: MLG SHOCK STRUT PISTON.

The MLG piston is a 300M steel forging with an abrasion-resistant polyurethane enamel surface finish on the lower portions. The upper portion of the piston is housed in the main cylinder to transfer axial landing shock into the hydraulic/pneumatic chambers. The piston lower portion contains the axle and braking mechanisms. Torque link fittings join the piston to the cylinder. Landing, braking, turning and taxi loads are transferred into the MLG assembly from the piston. Adverse landing conditions, residual hoop stresses and a salt-laden atmosphere can cause damage in the part. One per MLG.

DEFECTS: Circumferential cracks near the base of the upper piston region, longitudinal stress corrosion cracks along the forging parting plane, radial cracks around the torque link attachment, circumferential cracks near the piston-to-cross tube transition.

ACCESS: MLG fully extended, pistons maximum withdrawn from cylinder.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for all areas; magnetic particle (para. 1.5.3.2 circ.) can also be used for parting plane.

Backup: Magnetic particle (para. 1.5.3.2 circ.) for ultrasonic inspection verification

PROCEDURE NO. 5-612, Figure 5-9

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: MAIN LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.1)

COMPONENT/AREA DESCRIPTION: MLG MAIN CYLINDER (SHOCK STRUT):

The MLG main cylinder is a 300M steel forging having an abrasion-resistant polyurethane enamel exterior finish. The cylinder receives the MLG main piston and absorbs landing shock loads, reacts landing, braking, turning and taxi loads. Two upper arms of the strut mate to the trunnion fittings in the wheel well ribs and to the retraction actuator fittings. The lower drag brace attaches to a lug on the lower cylinder portion. Adverse landing, rollout, and taxi conditions could result in damage to the main cylinder. Additionally, breakdown of the finish system in the presence of residual hoop stresses and salt-laden atmosphere may result in stress corrosion if the surface finish is damaged.

DEFECTS: Radial cracks in the lower drag brace mating lug and the retraction actuator lugs, circumferential cracks in the trunnion dowels and longitudinal stress-corrosion cracks along the forging parting plane.

ACCESS: MLG fully extended. Trunnion pin must be removed for inspection.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B & C) for the lugs and forging parting plane on the cylinder portion; magnetic particle (para. 1.5.3.2 circ.) for the forging parting plane on the upper sections and trunnion dowels.

Backup: Magnetic particle (para. 1.5.3.2 circ.) for ultrasonic inspection verification.

PROCEDURE NO. 5-613, Figure 5-9

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: MAIN LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.1)

COMPONENT/AREA DESCRIPTION: MLG TORQUE ARM: There are two torque arms per landing gear (upper and lower) which are linked together at a pivot joint and attached to the MLG cylinder and MLG piston, respectively. They are made from a 300M steel forging and have an abrasion-resistant polyurethane enamel surface finish. The torque arms are subjected to high bending and shear loads during taxi turns.

DEFECTS: Radial cracks in the pivot attachment holes and transverse edge cracks in the body of the arm, particularly near the lug areas.

ACCESS: MLG fully extended. For backup inspection, the pivot joint may have to be disassembled.

NDT TECHNIQUES: Primary: Magnetic particle (para. 1.5.3.2 long & circ.)
Backup: Strip paint and use fluorescent penetrant (para. 1.5.2.1 Fig. 1-9 or 1-10).

PROCEDURE NO. 5-614, Figure 5-9

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: MAIN LANDING GEAR

(X) POSTFLIGHT

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.1)

COMPONENT/AREA DESCRIPTION: MLG LOWER LOCK BRACE: This part is a 300M steel forging and has an abrasion-resistant polyurethane enamel surface finish. The fitting works in conjunction with the upper lock brace to lock the MLG in the extended position during landing and ground operations. During retraction it is subject to bending and shear loads which may result in fatigue damage. The fwd end of the brace attaches to the upper and lower drag brace juncture. One per MLG.

DEFECTS: Radial cracks in the fwd and aft lugs emanating from the bolt holes.

ACCESS: MLG fully extended. The lower/upper lock brace joint may have to be disassembled for backup inspection, and local surface finish removed.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for the lug areas.

Backup: Magnetic particle (para. 1.5.3.2 circ.) or fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).

PROCEDURE NO. 5-615, Figure 5-9

TYPE INSPECTION

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

(X) POSTFLIGHT

SUBASSEMBLY: MAIN LANDING GEAR

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.1)

COMPONENT/AREA DESCRIPTION: MLG UPPER LOCK BRACE. The upper lock brace is a 300M steel forging with an abrasion-resistant polyurethane enamel surface finish system. The fitting serves to lock the landing gear in the extended position during landing and ground maneuvers. During landing-gear retraction the fitting must withstand bending and shear loads. The safe-life designed fitting may accumulate damage due to fatigue or overstress in hard landings. The aft end of the fitting attaches to the lock brace support beam. One per MLG.

DEFECTS: Radial cracks in the end lugs emanating from the attachment bolt holes.

ACCESS: MLG fully extended. For backup inspection, the lower/upper lock brace joint may have to be disassembled and local surface finish removed.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B).
Backup: Magnetic particle (para. 1.5.3.2 circ.).

PROCEDURE NO. 5-616, Figure 5-9

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: MAIN LANDING GEAR

(X) POSTFLIGHT

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.1)

COMPONENT/AREA DESCRIPTION: MLG LOWER DRAG BRACE. This 300M steel fitting connects to the upper drag brace and the MLG main cylinder. It is made from flash-welded tubing or a forging and has an abrasion-resistant polyurethane enamel surface finish. Adverse landing, braking and taxi conditions may produce fatigue or overstress problems in the mating lugs or welds.

DEFECTS: Radial cracks in the lug holes or circumferential cracks in the welds.

ACCESS: MLG fully extended. For backup inspection, the lower drag brace may have to be disassembled from the trunnion and/or upper drag brace.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) for lug areas; magnetic particle (para. 1.5.3.2 circ) for body.

Backup: Magnetic particle (para 1.5.3.2 circ) for ultrasonic inspection verification.

PROCEDURE NO. 5-617, Figure 5-9

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: MAIN LANDING GEAR

(X) POSTFLIGHT

DRAWING(S): VL72-000103A and 73MA5769
(Fig. 1.9.1)

COMPONENT/AREA DESCRIPTION: MLG UPPER DRAG BRACE. This wish-bone fitting is attached to the lower drag brace at $Y_o \pm 138$ and to the trunnion fittings at $Y_o \pm 107$ and ± 169 . The fitting is made of 300M steel flash-welded tubing or forging and has an abrasion-resistant polyurethane enamel surface finish. The lugs on the lower/aft extremity that mate with the lower drag brace lug and the dowels on the upper/fwd end that mate with the trunnion fittings in the MLG well inbd/outbd ribs are subject to cracking under adverse landing, braking or taxi conditions. Additional problems may involve the welds and the upper lugs (interior base region).

DEFECTS: Radial cracks in the mating lugs; circumferential cracks in the trunnion dowels and the welds.

ACCESS: The MLG fully extended. For backup inspection disassemble drag brace attachment to fuselage on MLG wheel well rib.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) and/or magnetic particles (para. 1.5.3.2 circ).

Backup: Magnetic particle (para. 1.5.3.2 circ.) for ultrasonic inspection verification.

- PROCEDURE NUMBER
 M - MAGNETIC PARTICLE INSPECTION
 U-S - ULTRASONIC SHEAR WAVE INSPECTION

INSPECT: LUG BOLT HOLES
 LUG BASE INTERSECTIONS
 AXLE SPLINES AND BODY
 MAIN CYLINDER PARTING PLANE
 MAIN PISTON PARTING PLANE
 CROSS TUBE BODY INTERSECTIONS

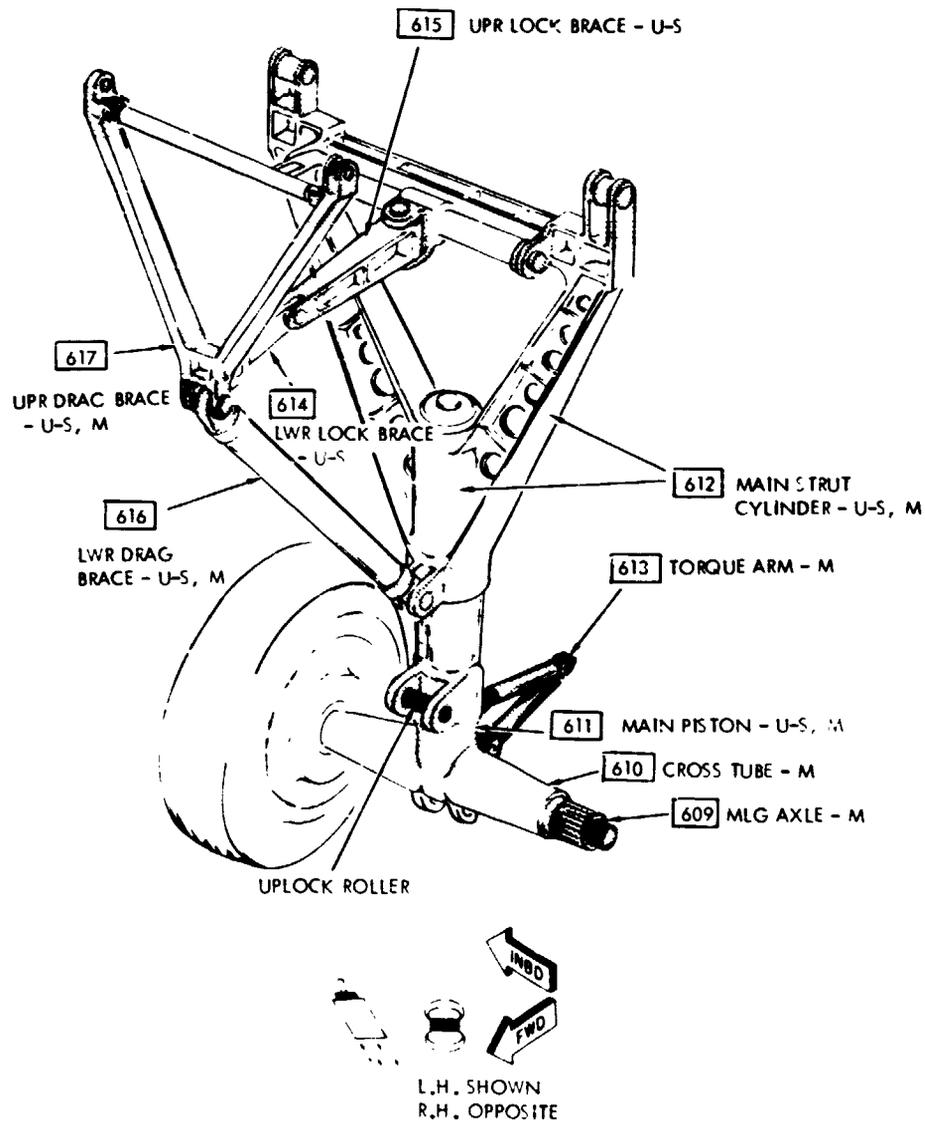


Figure 5-9. Main Landing Gear Assembly

PROCEDURE NO. 5-618, Figure 5-10

<u>MAJOR ASSEMBLY:</u>	ORBITER, WING, ZONE 6	<u>TYPE INSPECTION</u>
<u>SUBASSEMBLY:</u>	LEADING EDGE SPAR	(X) POSTFLIGHT
<u>DRAWING(S):</u>	GRUMMAN B91800001, VL72-000091	

COMPONENT/AREA DESCRIPTION: LEADING EDGE SPAR CAPS AT WING RIB/SPAR ATTACHMENTS AND LEADING EDGE ATTACH BRACKETS.

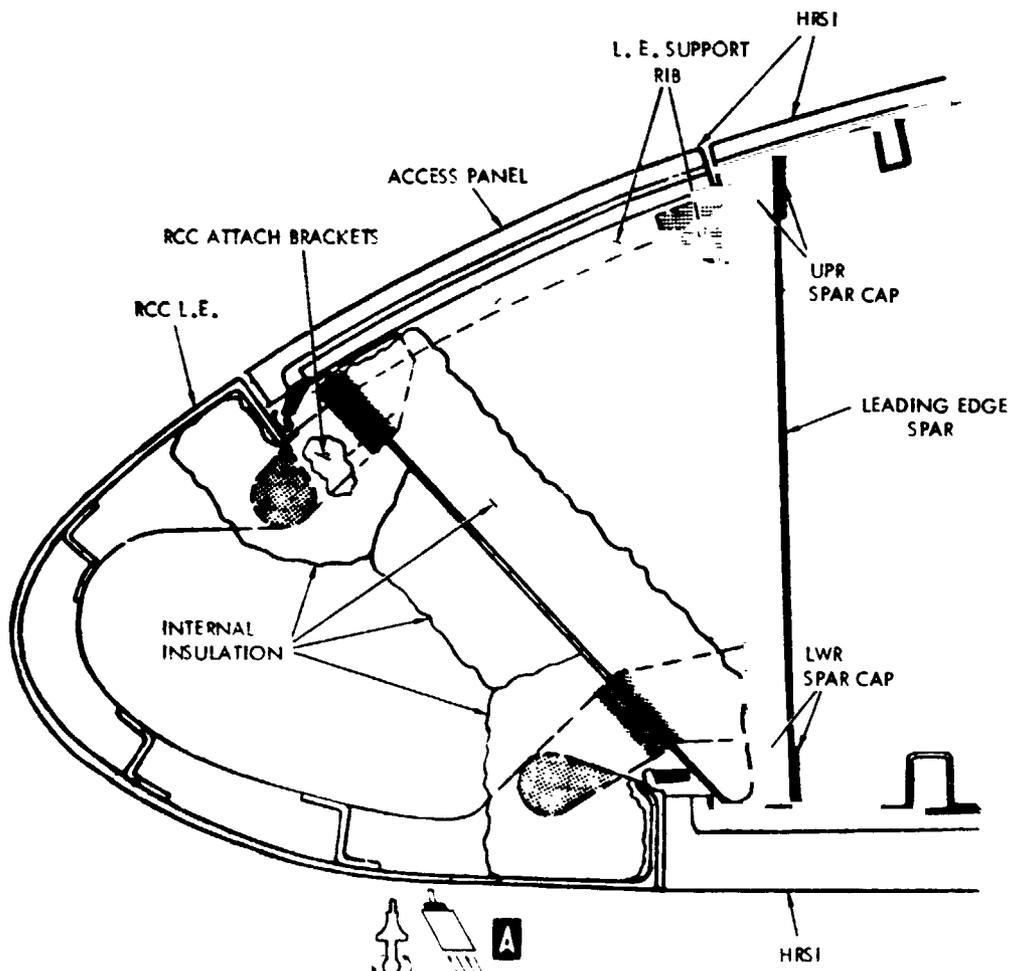
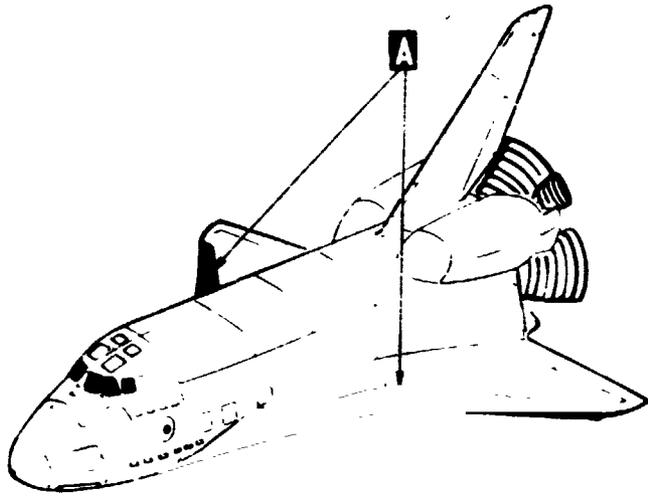
These 2024-T81 aluminum alloy spar caps are located along the upper and lower edges of the wing leading edge spar, which forms the forward closure of the double-delta wing structure. The spar caps should be inspected at certain wing rib/spar attachment locations such as at Y_w 171.2 (X_w 1009.75), Y_w 184 (X_w 1040), Y_w 198 (X_w 1071.5), Y_w 254 (X_w 1132), Y_w 312.5 (X_w 1191), Y_w 372.5 (X_w 1249) and Y_w 435 (X_w 1307). The leading edge attach structure should be inspected generally along the wing from X_w 1040 aft. Fatigue damage may be induced in tension and shear by flight loads and high headwinds during high-Q boost.

DEFECTS: Radial cracks at fastener holes and edge cracks in the spar cap at the rib/spar attachment points; radial cracks at fastener holes in the leading edge attach structure.

ACCESS: The leading edge spar caps and leading edge attach brackets are accessible at the designated areas by removing the appropriate leading edge access panels. Backup inspection will require removal of surface finish in suspect area.

NDT TECHNIQUES: Primary: Eddy current (para. 1.5.4.4) and/or ultrasonic shear wave (para. 1.5.5.3 C)

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



LEADING EDGE SPAR CAP AND LEADING EDGE ATTACH BRACKETS

Figure 5-10. Leading Edge Spar Caps

PROCEDURE NO. 5-619, Figure 5-11

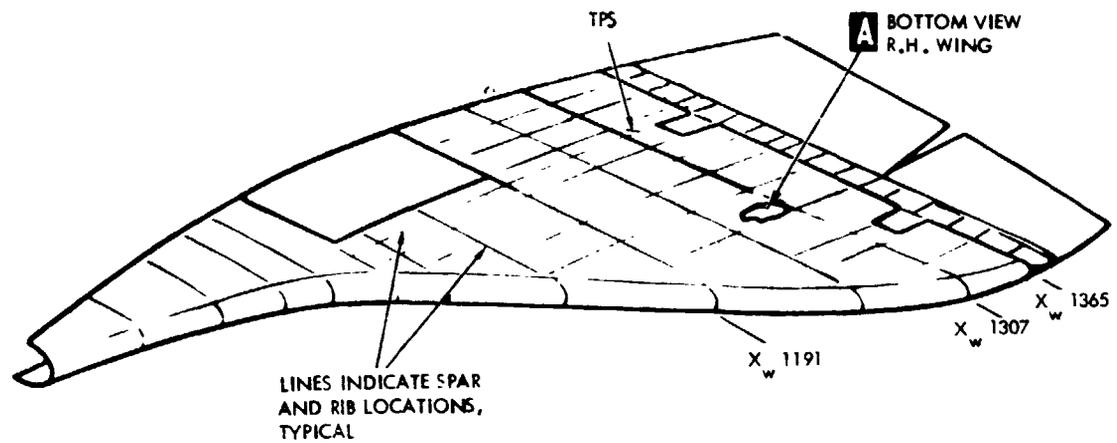
<u>MAJOR ASSEMBLY:</u>	ORBITER, WING, . NE 6	<u>TYPE INSPECTION</u>
<u>SUBASSEMBLY:</u>	WING SKIN PANELS	(X) POSTFLIGHT
<u>DRAWING(S):</u>	GRUMMAN B91B00001, 73MA5769 (Fig. 1.5.1-1.5.4)	

COMPONENT/AREA DESCRIPTION: WING LOWER SKIN PANELS: The skin lower surface panels may be subject to fatigue damage in the areas where highly loaded wing spars and ribs intersect. Of particular interest are, generally, the areas of skin where the Y_w 254, 226, 198, 167 and 114 ribs intersect the X_w 1365, 1307, 1249, 1191, 1132 and 1047 spars. The critical load conditions are high compression during high-Q boost and tension during cruise headwinds; compressive loads during landing may also contribute. The skins are made of 2024-T81 formed sheet covered externally with the HRSI/LRSI TPS and reinforced in a fail-safe design approach by the use of stringers.

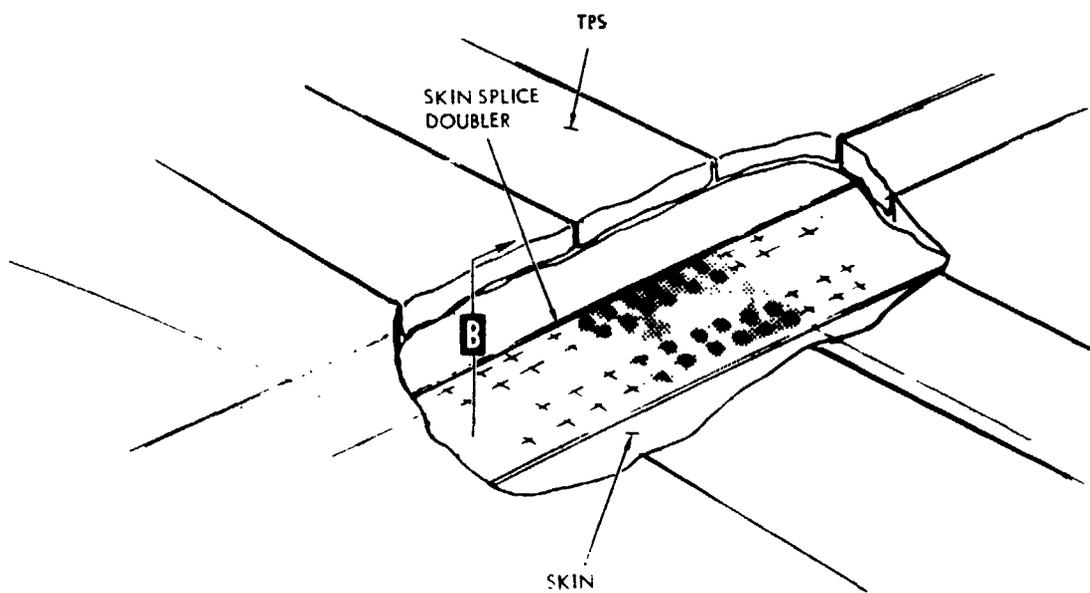
DEFECTS: Fore-to-aft cracks (chordwise) emanating at fastener holes in the skin along the spar rib intersections.

ACCESS: Enter appropriate wing box area through wing access openings to place x-ray film. X-ray machine is placed on ground or platform outside of wing, aimed at desired area on lower wing surface (not necessary to remove local TPS for primary NDE) Local TPS must be removed for backup inspection.

NDT TECHNIQUES: Primary: X-ray radiography (para. 1.5.6.2)
Backup: Eddy current (para. 1.5.4.4) or fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

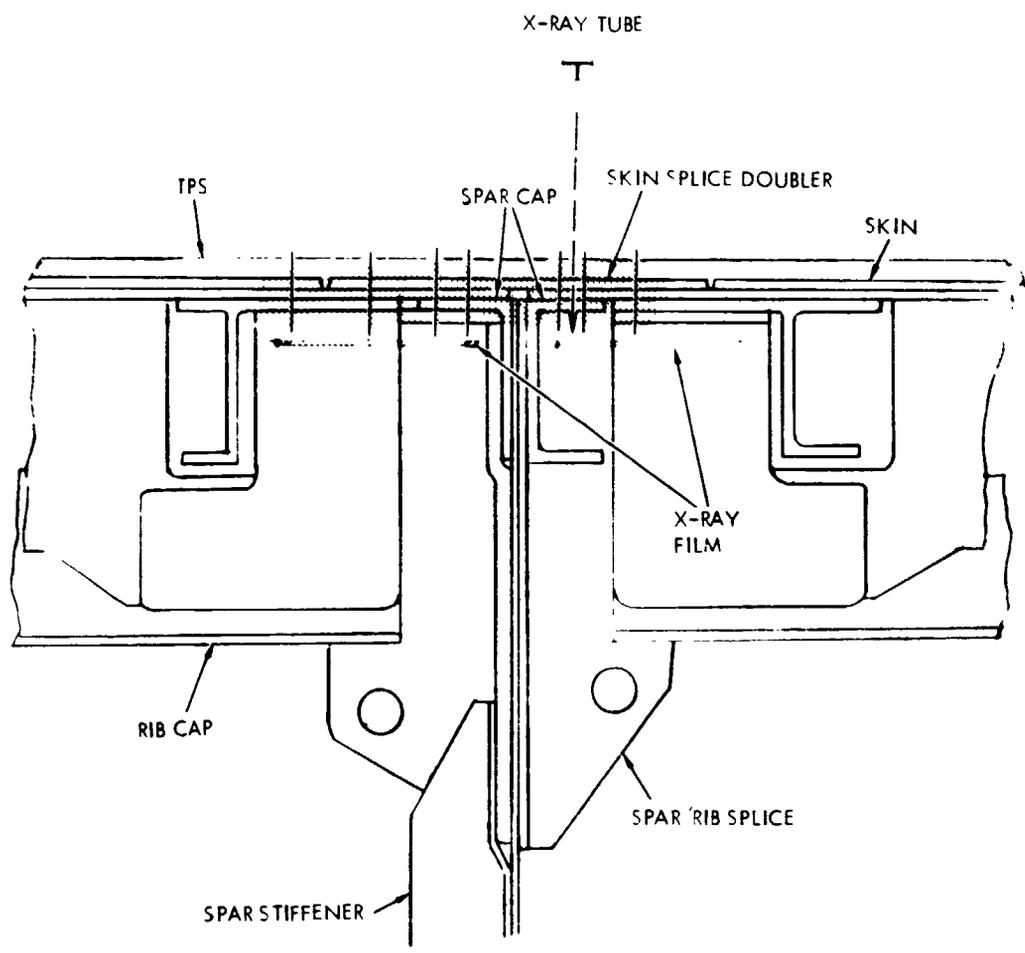


DEFINITION OF NUMBER AND LOCATION OF INSPECTION POINTS TBD FOR UPPER AND LOWER WING SURFACE



A WING SKIN PANEL SPLICE DOUBLER AT RIB/SPAR LOCATIONS

Figure 5-11. Wing Lower Skin Panels (Sheet 1 of 2)



B

WING SKIN, SPAR RIB INTERSECTIONS, TYPICAL
LKG INBD

Figure 5-11. Wing Lower Skin Panels (Sheet 2 of 2)

PROCEDURE NO. 5-620, Figure 5-12

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: WING SPARS

(X) POSTFLIGHT

DRAWING(S): GRUMMAN B91B00001, 73MA5769
(Fig. 1.5.1-1.5.4)

COMPONENT/AREA DESCRIPTION: WING SPAR CAPS: The wing spar caps are made of 2024-T81 aluminum alloy formed sheet and have a zinc chromate primer and Supercorapon 515-700 paint interior surface finish. The caps are subject to damage in the area of rib and spar truss splice attachments due to high tensile loads during high-Q boost, compression and tension during atmospheric flight and landings. The areas that are of particular interest are located at the intersections of highly loaded ribs and spars (such as generally along the X_w 1365, 1307, 1191, 1132, 1040 and leading edge spars and their intersections with the fuselage, Y_w 167, 198, 254, 312 and 342 ribs).

DEFECTS: Spanwise cracks around spar cap-to-splice fitting fastener holes in the vertical web portion of the cap; chordwise cracks around fastener holes in the horizontal flange portion of the caps where attachment is made to skin or splice fittings.

ACCESS: Enter appropriate wing box area through wing access openings.

NDT TECHNIQUES: Primary: Eddy current surface probe (para. 1.5.4.4) or ultrasonic surface wave (para. 1.5.5.1) techniques.

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

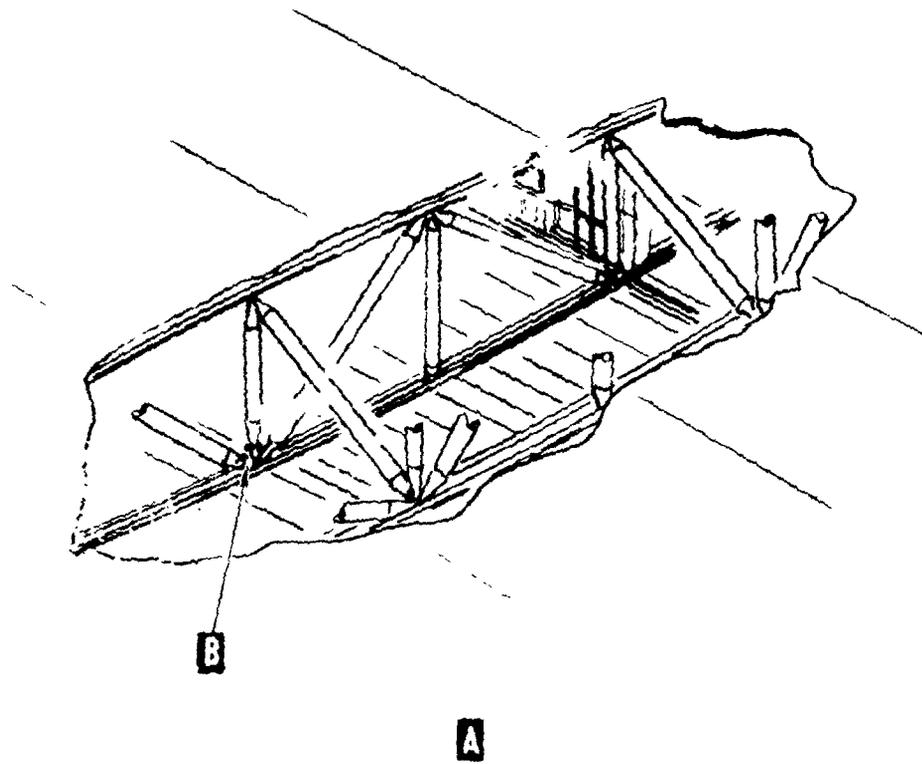
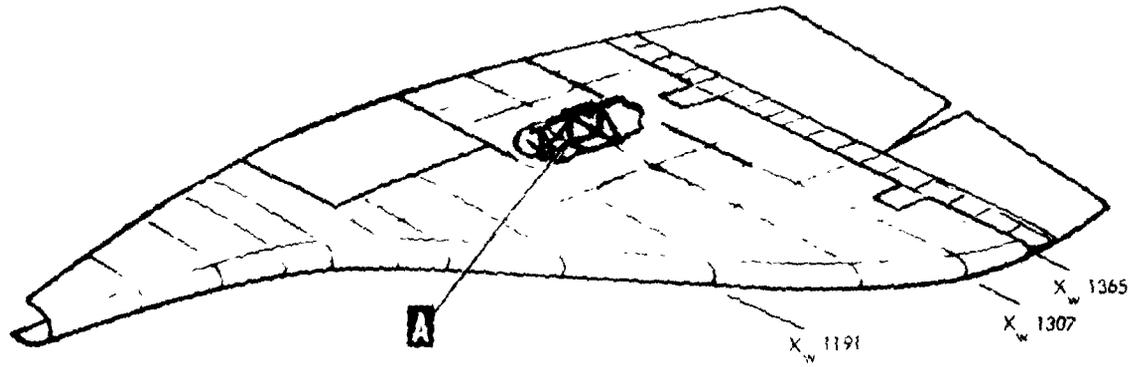


Figure 5-12. Wing Spar Caps (Sheet 1 of 2)

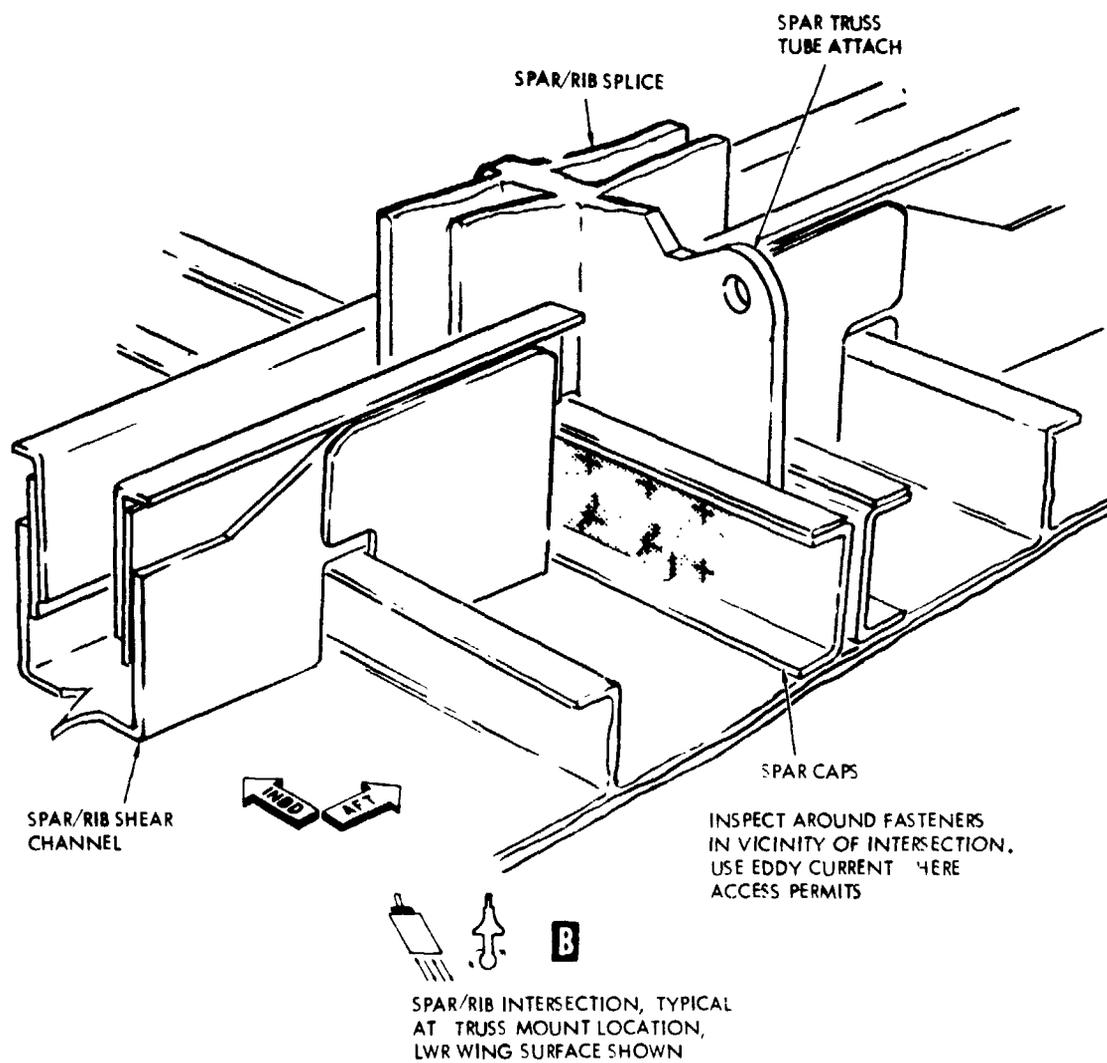


Figure 5-12. Wing Spar Caps (Sheet 2 of 2)

PROCEDURE NO. 5-621, Figure 5-13

<u>MAJOR ASSEMBLY:</u>	ORBITER, WING, ZONE 6	<u>TYPE INSPECTION</u>
<u>SUBASSEMBLY:</u>	WING SPARS	(X) POSTFLIGHT
<u>DRAWING(S):</u>	GRUMMAN B91B00001, 73MA5769 (Fig 1.5.1-1.5.4)	

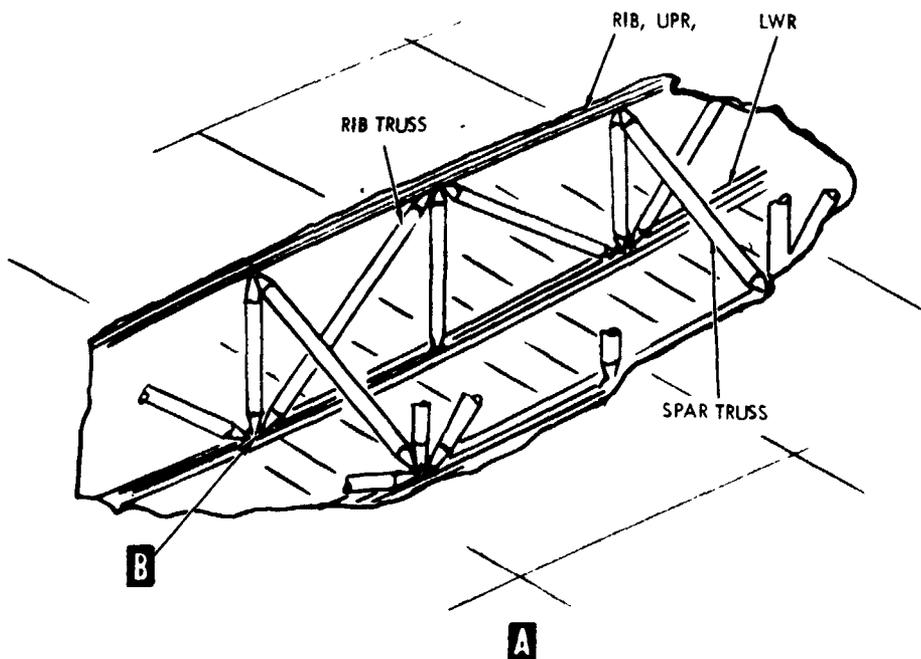
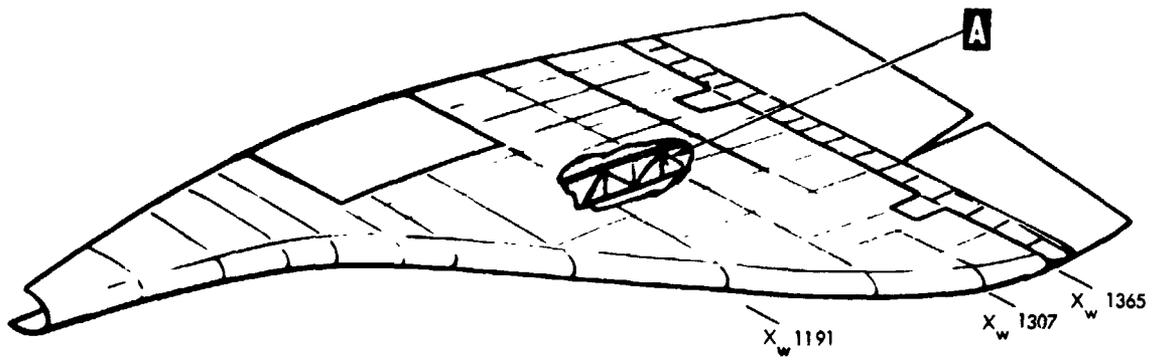
COMPONENT/AREA DESCRIPTION: WING RIB CAPS: The rib caps are made of 2024-T81 aluminum alloy formed sheet and have a zinc chromate primer and Super-corapon 515-700 paint surface finish. The caps are subjected to high tensile loads during high-Q boost and tension/compression during atmospheric flight and landing. The caps may accumulate fatigue damage near certain highly loaded rib/spar splices. In the suspect areas, the caps are sandwiched between the rib/spar attachment flanges and rib channels. The areas are generally along the fuselage intersection, along the wing box rib and loaded ribs intercepting the leading edge spar and the wing aft spar.

DEFECTS: Vertically oriented through-cracks emanating from fastener holes where attachment is made to the rib/spar fitting.

ACCESS: Enter the appropriate wing box area through wing box access openings. Direct access to the affected portion of the caps is not available due to build-up configuration.

NDT TECHNIQUES: Primary: Radiography (para. 1.5.6.2) (gamma-ray (para. 1.5.6.3) may be best because of confined space).

Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)



WING TRUSS, RIB, TYPICAL

Figure 5-13. Wing Rib Caps (Sheet 1 of 2)

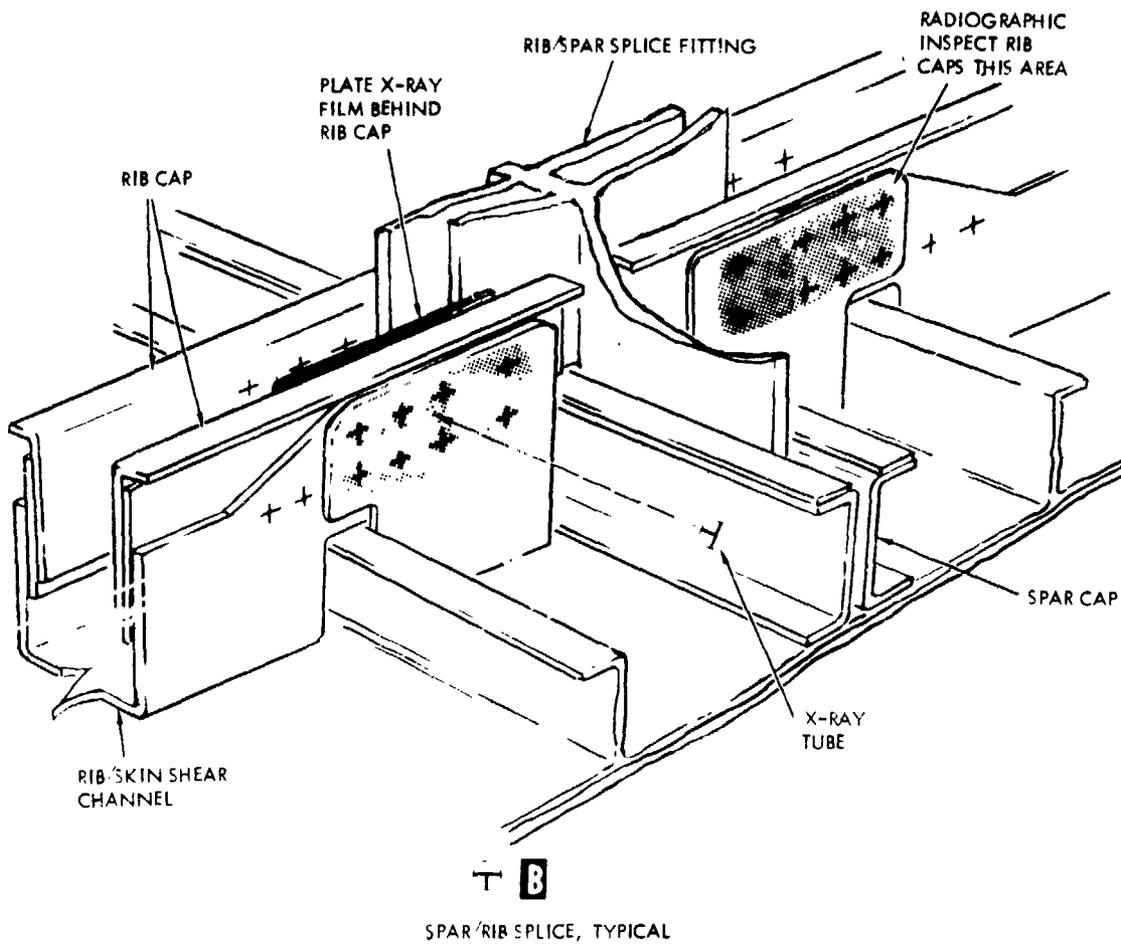


Figure 5-13. Wing Rib Caps (Sheet 2 of 2)

PROCEDURE NO. 5-622, Figure 5-14

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6 TYPE INSPECTION

SUBASSEMBLY: WING RIBS (X) POSTFLIGHT

DRAWING(S): GRUMMAN B91B00001, 73MA5769
(Fig. 1.5.1-1.5.4)

COMPONENT/AREA DESCRIPTION: WING SPAR/RIB SPLICES: The spar/rib splices are made of 2024-T81 formed sheet and have a zinc chromate primer and Supercorapon 515-700 paint surface finish. The splice fittings experience high tensile loads during high-Q boost and tension/compression during atmospheric flight along the X and Y axes. The fittings serve as a common attachment point for spar and rib caps and trusses. The locations of the fittings most likely to accumulate damage during the service life of the vehicle are along the wing aft spar, rear spar, mid spar and front spar.

(Coordinate this inspection with inspection of rib and spar caps.)

DEFECTS: Radial cracks in the truss attachment lugs; vertically oriented cracks emanating from fastener holes on the rib and spar attachment flanges; and edge cracks where the rib truss attachment flanges blend into the spar truss attachment flanges.

ACCESS: Enter appropriate wing box through wing access openings to place radiographic film and source.

NDT TECHNIQUES: Primary: Radiographic (para. 1.5.6.2) (gamma ray (para. 1.5.6.3) source may be best due to confined area); eddy current surface probe (para. 1.5.4.4) for flange edge cracks.

Backup: Eddy current (para. 1.5.4.4) or penetrant (para. 1.5.2.1 Fig. 1-9) after removal of suspected truss and/or fastener.

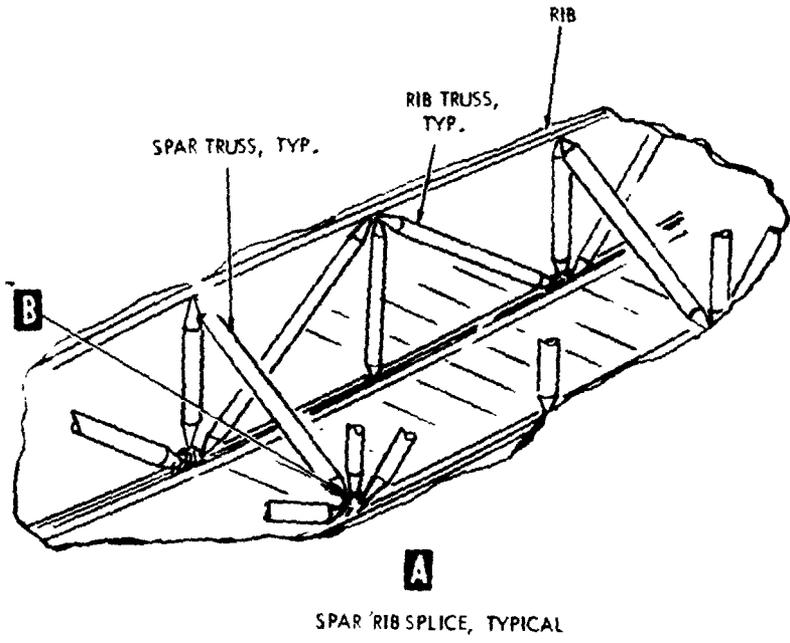
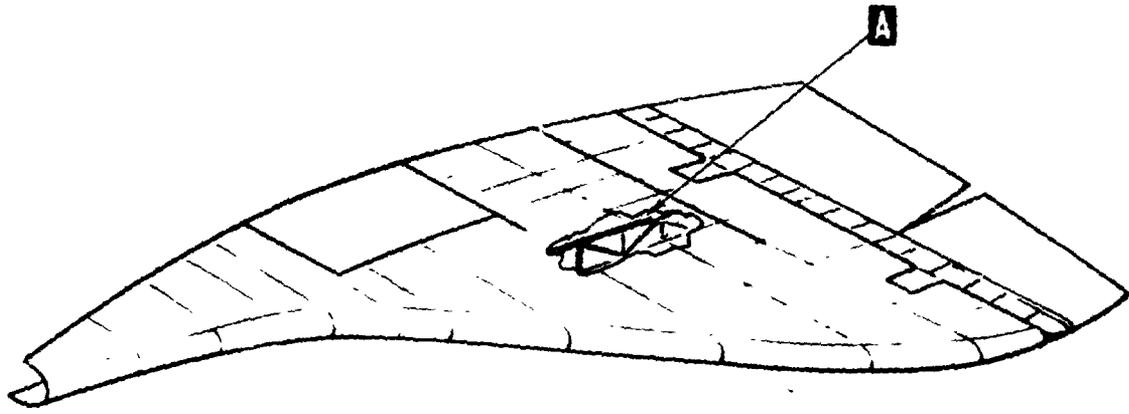


Figure 5-14. Wing Spar/Rib Splices (Sheet 1 of 2)

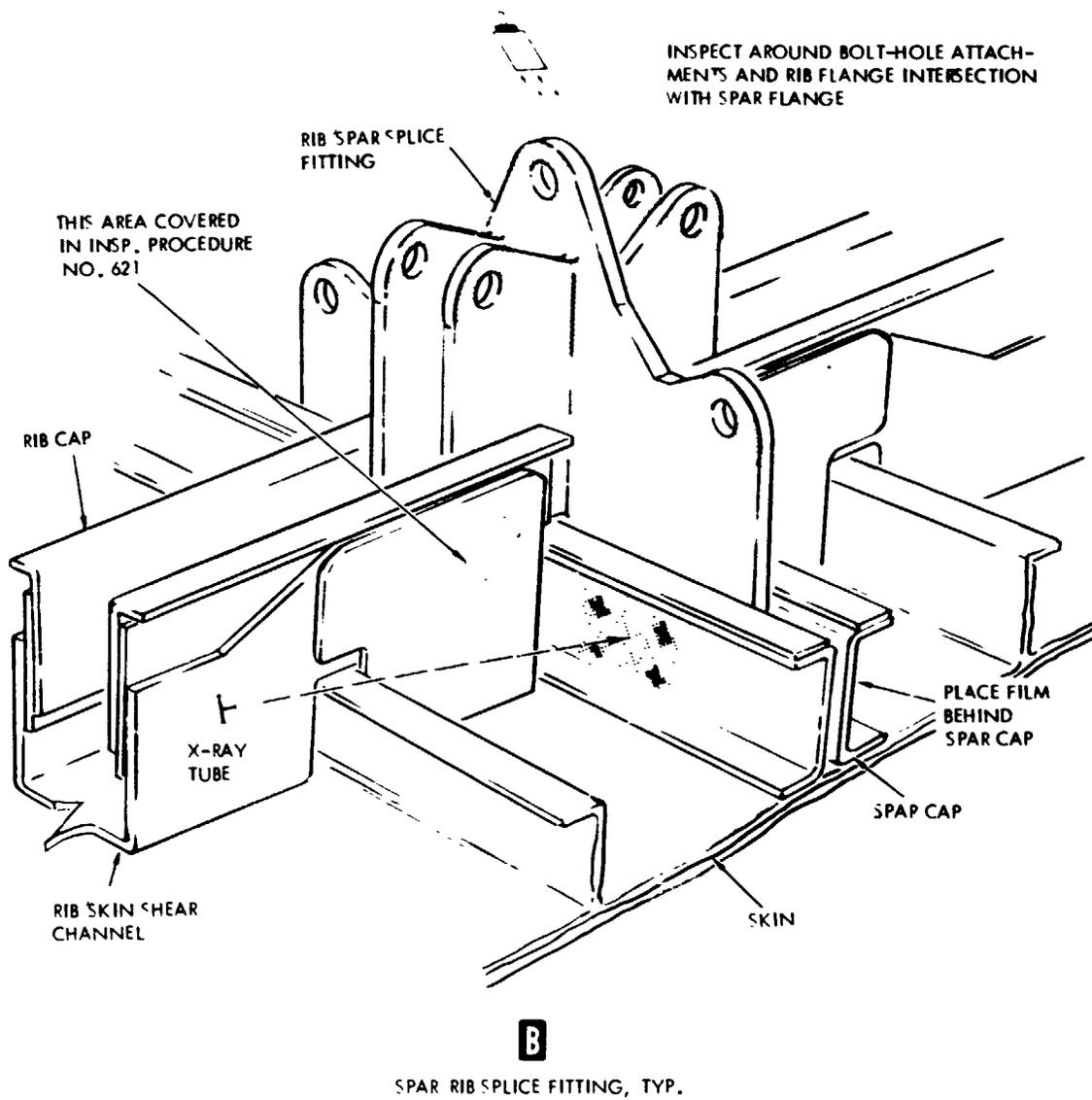


Figure 5-14. Wing Spar/Rib Splices (Sheet 2 of 2)

PROCEDURE NO. 5-623, Figure 5-15

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: ELEVON ACTUATORS

(X) POSTFLIGHT

DRAWING(S): GRUMMAN B91B00001, Fig. 1.5.4
73MA5769

COMPONENT/AREA DESCRIPTION: ELEVON ACTUATOR ATTACH FITTINGS.

These fittings are machined from Ti-6AL-6V-2.5Sn titanium alloy plate. There is one fitting per elevon section, two per wing, which attach to the elevon front spar and are supported by the wing aft spar and rear beam. The actuator fittings are located aft of the wing aft spar at wing stations Y_w 212 and Y_w 387.5. The fittings carry the loads necessary to actuate and deploy the elevons during cross range, glide flight, landing and ferry flight, in which the fittings react high-Q compression and headwind tensile loads. Under repetitions of this load profile, the lug areas of these fittings may develop fatigue problems.

DEFECTS: Fatigue cracks may originate in the attachment holes in the lugs at the fore and aft ends of the fittings and at the attachments to the elevon front spar and the wing aft spar.

ACCESS: The actuator support rib forward ends are accessible by removing two actuator access panels on the wing surface at the given actuator locations. The attachments to the elevons are accessible by removing the aft spar closure panels at the same wing stations. For backup inspection, the hinge pin will have to be removed from lugs.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) and eddy current surface probe (para. 1.5.4.4).

Backup: Eddy current bolt hole (para. 1.5.4.3) and fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).

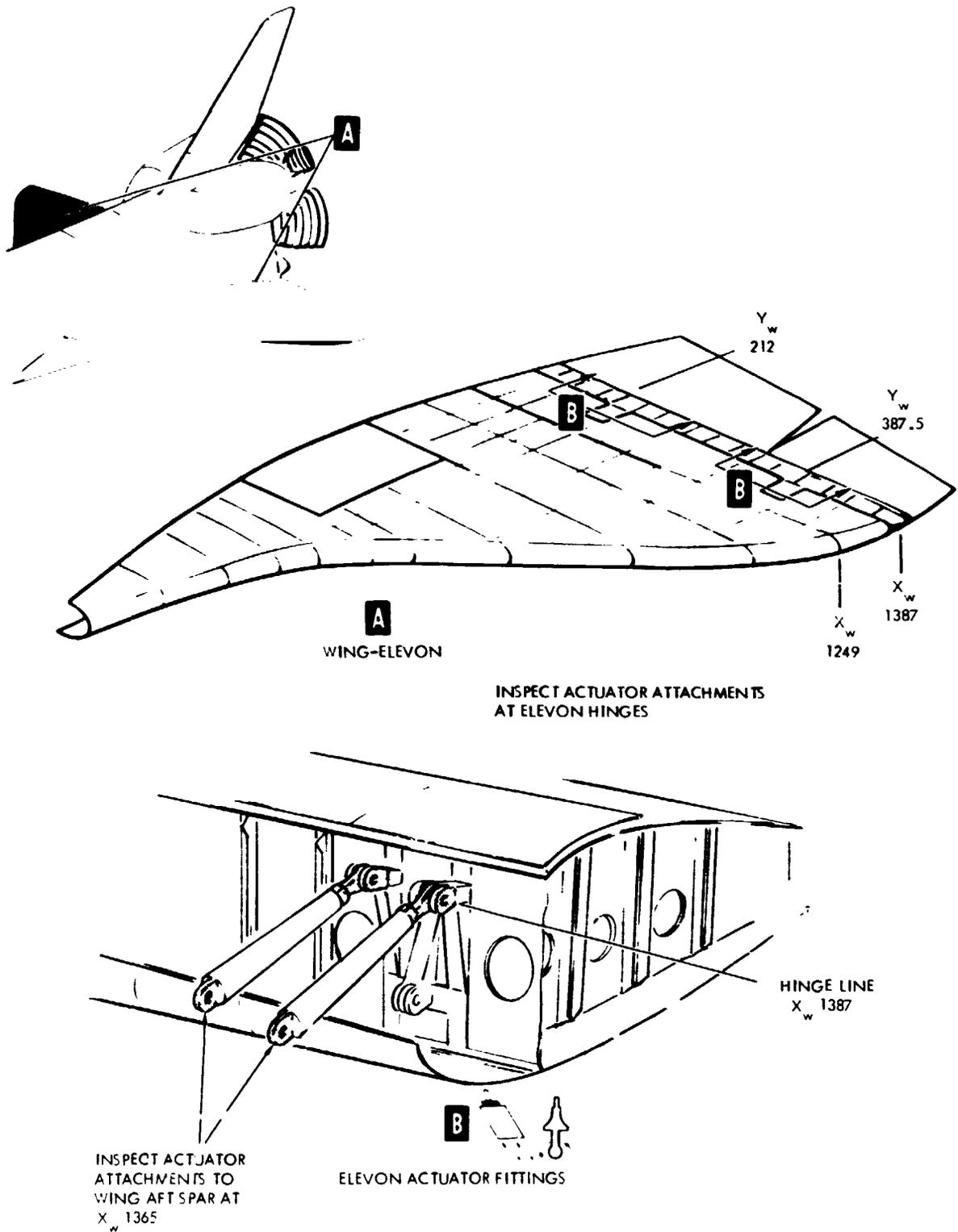


Figure 5-15. Elevon Actuator Attach Fittings

PROCEDURE NO. 5-624, Figure 5-16

<u>MAJOR ASSEMBLY:</u>	ORBITER, WING, ZONE 6	<u>TYPE INSPECTION</u>
<u>SUBASSEMBLY:</u>	ELEVON HINGES	(X) POSTFLIGHT
<u>DRAWING(S):</u>	GRUMMAN B91B00001, Fig. 1.5.4 of 73MA5769	

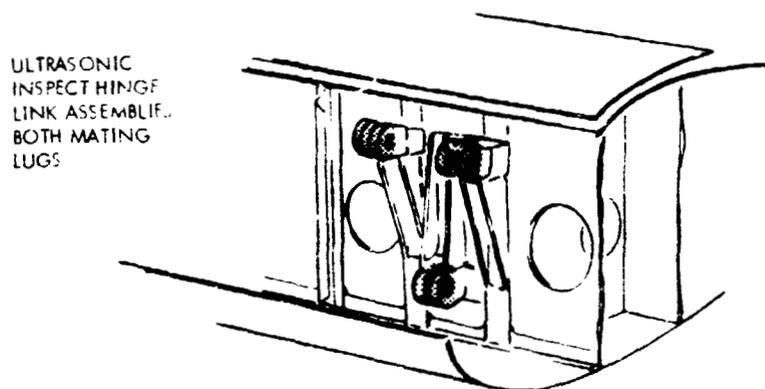
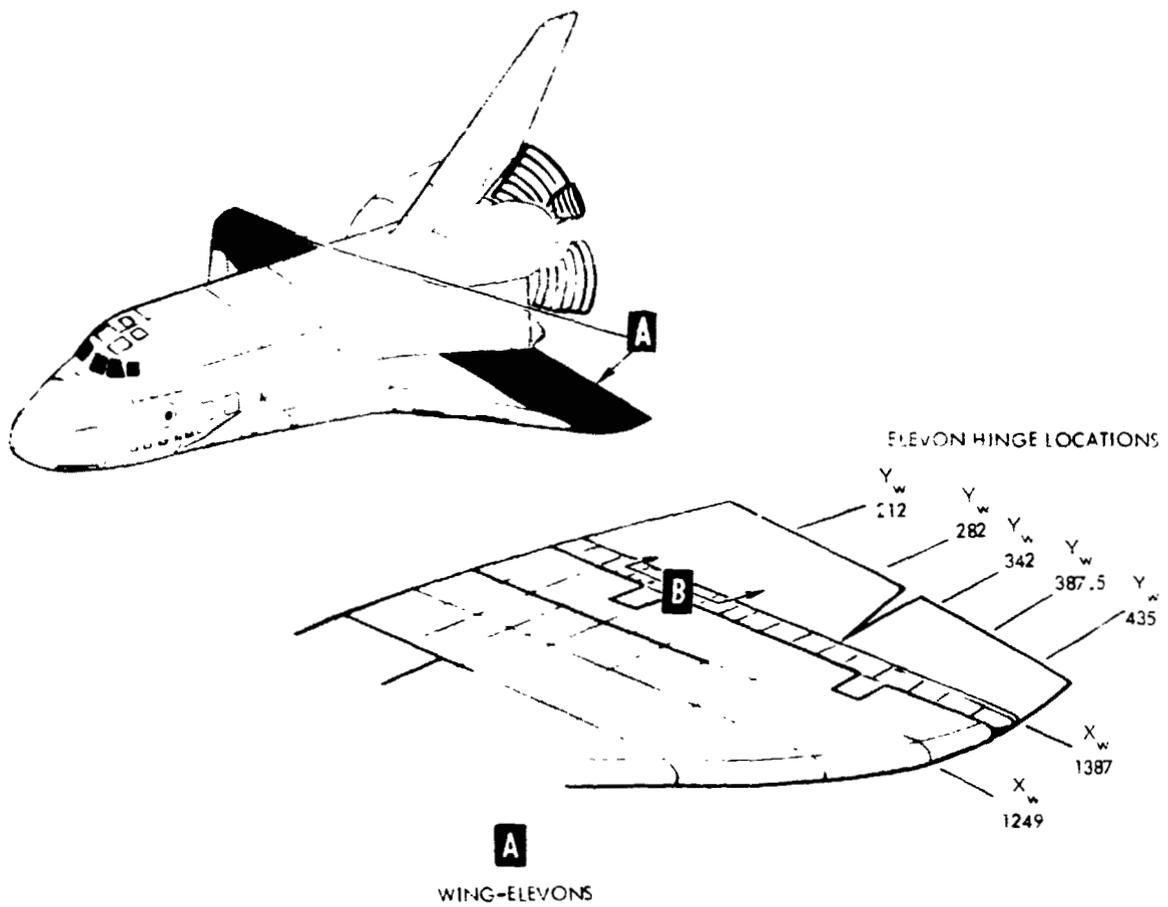
COMPONENT/AREA DESCRIPTION: ELEVON HINGES. Each elevon is hinged at three locations along the X_o 1387 hinge line. The hinges are at $Y_w \pm 435$, $Y_w \pm 387.5$, $Y_w \pm 342.5$, $Y_w \pm 282$, $Y_w \pm 212$, and $Y_w \pm 147.5$. The components are made of Ti-6AL-6V-2.5Sn titanium machined plate. The hinges are integrally stiffened structures which are attached to the aft side of the wing aft spar lower area and a lug on the elevon which are mated by the use of a pivot pin. The safe-life hinges experience high tensile loads during high-Q boost, and high headwind compression.

DEFECTS: Under repeated adverse conditions during ascent, cross-range flight, glide and landing, cracks may develop from fatigue or overstress in either portion of the hinge, including the pivot pin and the hinge link assemblies at Y_w 282 and 342.

ACCESS: The hinges are accessible after removing the six aft spar closure panels and elevon thermal seal panels between wing aft spar and elevon front spar.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (para. 1.5.5.3 B) and fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).

Backup: Eddy current bolt-hole (para. 1.5.4.3) or fluorescent penetrant (para. 1.5.2.1 Fig. 1-9).



B

ELEVON HINGE AND ACTUATOR FITTINGS, TYPICAL

Figure 5-16. Elevon Hinges

PROCEDURE NO. 5-625, Figure 5-17

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: ELEVON

(X) POSTFLIGHT

DRAWING(S): GRUMMAN B91B00001 , 73MA5769
Fig. 1.5.4

COMPONENT/AREA DESCRIPTION: ELEVON HONEYCOMB SKIN PANELS:

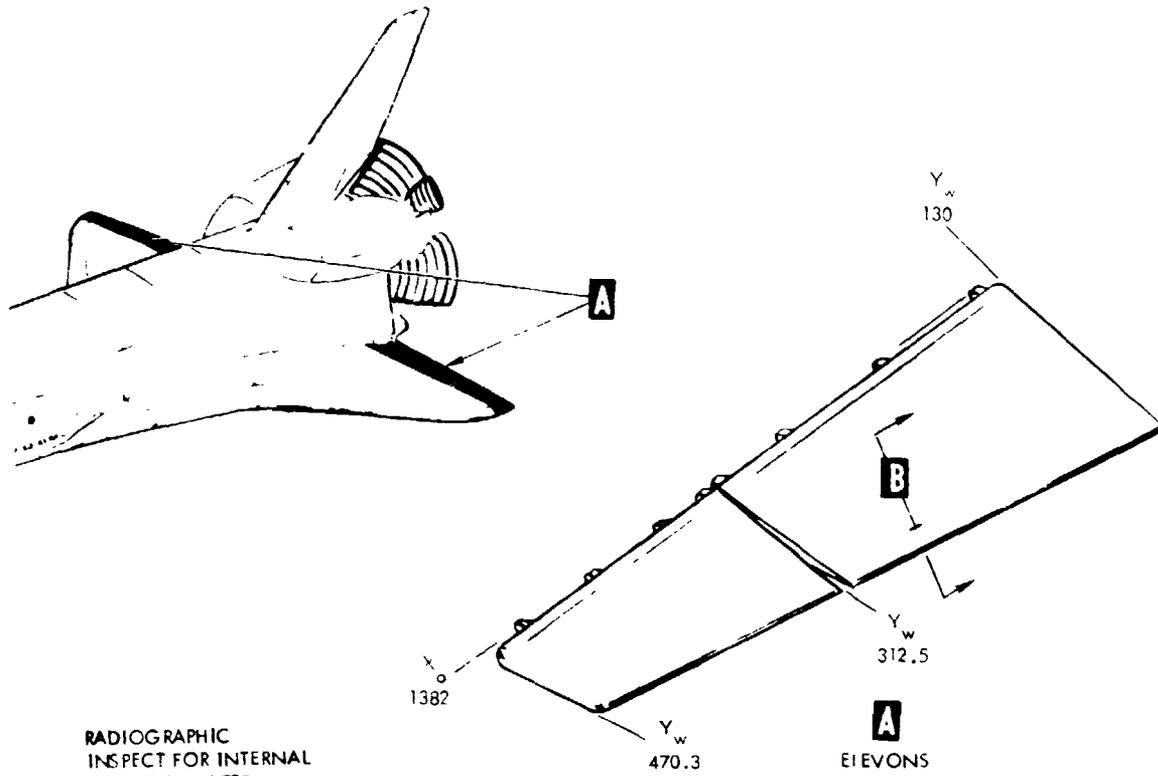
The elevon skins are made of honeycomb compound composites consisting of Ti-6Al-6V-2.5Sn titanium alloy face sheets and aluminum alloy core. The safelife designed panels experience tension loads during high-Q boost and high headwind compression. High vibroacoustic loads during lift-off and ascent can affect core-to-facesheet bonding. Entrapped moisture may freeze and burst core walls and/or combine with residual volatiles to create a weak, but corrosive alkaline solution. During landing, runway debris kicked up by the landing gear may damage lower elevon skins.

DEFECTS: Unbonds between core and facesheet; core damage due to internal water (corrosion and ice) or debris impact. If TPS is damaged by debris, the elevon skin may possibly be damaged.

ACCESS: The elevons are directly accessible from outside the vehicle. Numerous vent holes in the elevon front spar may provide adequate access for x-ray film placement inside the elevon box. For ultrasonic or thermographic inspections, TPS panels must be removed and elevon surface thoroughly cleaned.

NDT TECHNIQUES: Primary: X-ray (para. 1.5.6.2) for core general damage and water entrapment. Ultrasonic (para. 1.5.5.6) or thermography (para. 1.5.8.2) for disbond detection and corrosion.

Backup: For disbonds, use mechanical pull test for disbonds greater than TBD diameter.



RADIOGRAPHIC
INSPECT FOR INTERNAL
DAMAGE, WATER
ENTRAPMENT

ULTRASONIC INSPECT
FOR DISBONDS BETWEEN
FACE SHEET AND CORE

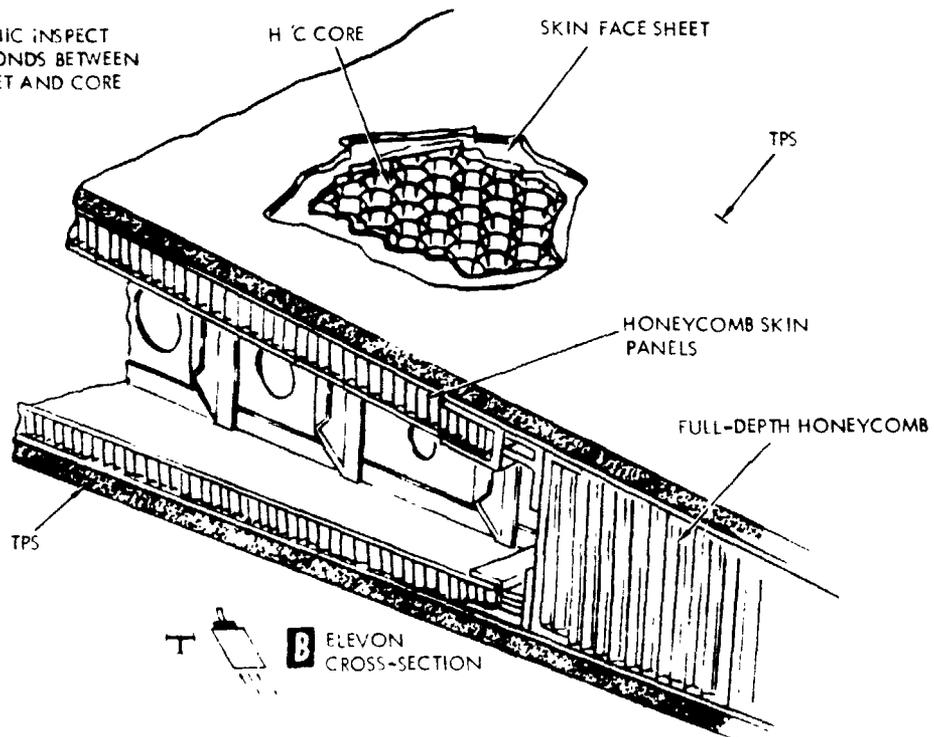


Figure 5-17. Elevation Honeycomb Skin Panels

PROCEDURE NO. 5-626, Figure 5-18

MAJOR ASSEMBLY: ORBITER, WING, ZONE 6

TYPE INSPECTION

SUBASSEMBLY: ELEVON

(X) POSTFLIGHT

DRAWING(S): GRUMMAN B91B00001, 73MA5769
Fig. 1.5.4

COMPONENT/AREA DESCRIPTION: ELEVON WEB STIFFENERS: Each elevon box contains four chordwise hinge/actuator ribs whose webs are stiffened by transverse angle members made of titanium-6Al-4V alloy formed sheet. Compressive and shear loads are imposed on these stiffeners when the elevons are deployed in aerodynamic flight. Vibroacoustic loading during launch and ascent may also impose tension/compression on these members.

DEFECTS: Transverse edge cracks at points along length of member, particularly near mid-span of the stiffener and at attachment to rib caps.

ACCESS: Access to each rib web stiffener is through the lightening holes in the elevon front spar. Thermal seals must be removed and elevon deployed up or down.

NDT TECHNIQUES: Primary: Optical borescope (para. 1.5.1.3)
Backup: Fluorescent penetrant (para. 1.5.2.1 Fig. 1-9)

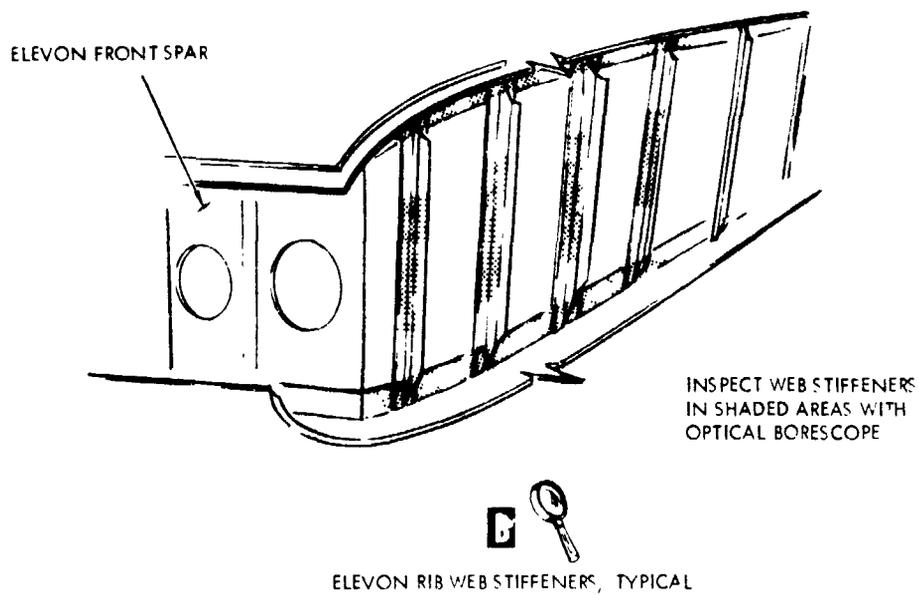
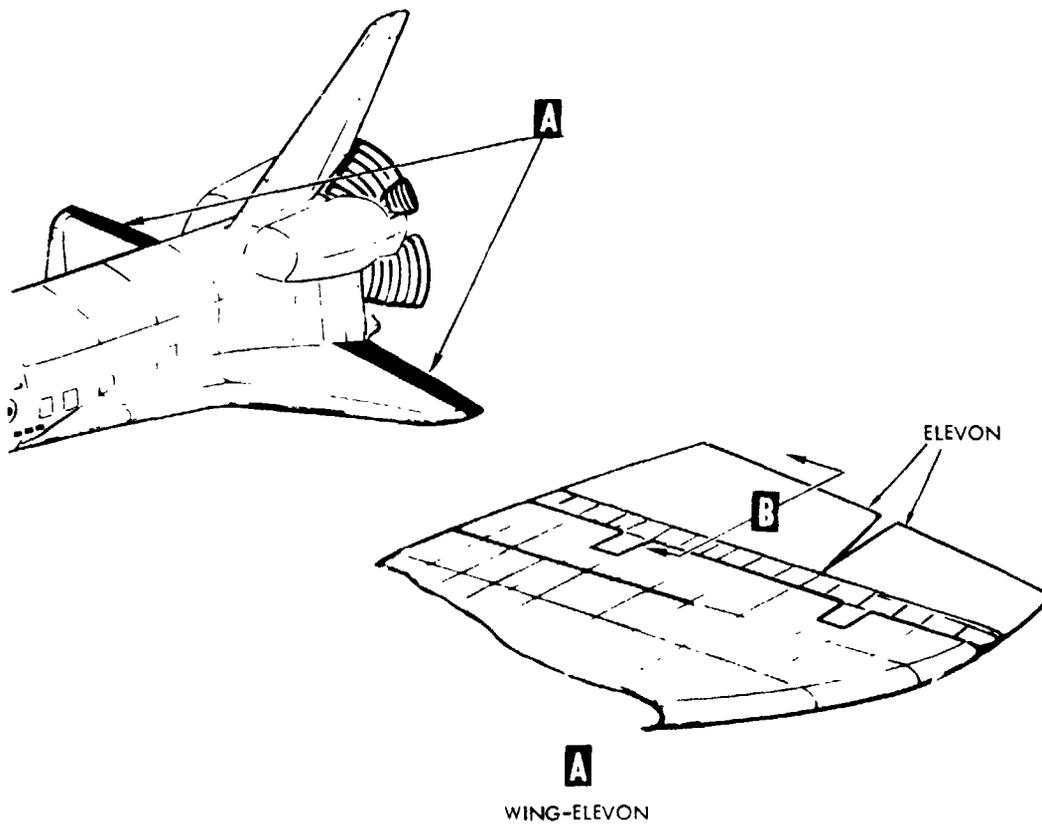


Figure 5-18. Elevon Web Stiffeners

SECTION 6. VERTICAL STABILIZER STRUCTURE

This section contains the NDE requirements for the vertical stabilizer skin, forward and rear spars, the rudder/speed brake hinges and actuator fittings, the rudder/speed brake spars and honeycomb skin, and the vertical stabilizer/aft-fuselage interface .

SECTION 6
TABLE OF CONTENTS

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
6-701	Vertical Stabilizer Front Spar Cap	6-1
6-702	Vertical Stabilizer - Fuselage Aft Attach Fitting	6-3
6-703	Vertical Stabilizer Skins	6-5
6-704	Vertical Stabilizer Rear Spar at Rudder , Lower Forward Edge	6-7
6-705	Rudder/Speed Brake Actuator and Hinge/ V.S. Rear Spar Attach Point	6-9
6-706	Rudder/Speed Brake Actuator/Hinge	6-11
6-707	Rudder Front Spar	6-15
6-708	Rudder/Speed Brake Rear Spar	6-17
6-709	Rudder/Speed Brake Honeycomb Skin Panels	6-19

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SECTION 6
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
6-1	Vertical Stabilizer Front Spar Caps	6-2
6-2	Vertical Stabilizer/Fuselage Aft Attachment	6-4
6-3	Vertical Stabilizer Skins	6-6
6-4	Vertical Stabilizer Rear Spar at Rudder Lower Forward Edge	6-8
6-5	Rudder/Speed Brake Actuator and Hinge/Vertical Stabilizer Rear Spar Attach	6-10
6-6	Rudder/Speed Brake Actuator/Hinge	6-13
6-7	Rudder Front Spar	6-16
6-8	Rudder Rear Spar	6-18
6-9	Rudder/Speed Brake Honeycomb Skin Panels	6-20

PROCEDURE NO: 6-701, FIGURE 6-1
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER
ZONE 7
SUBASSEMBLY: VERT STAB FRONT SPAR

TYPE INSPECTION:
(X) POSTFLIGHT

COMPONENT/AREA DESCRIPTION: VERTICAL STABILIZER FRONT SPAR CAP.

The front spar is made of 2124-T851 aluminum alloy extrusions and has a zinc chromate primer plus one coat of Supercorapon 515-700 finish. The V.S. front spar attaches to the aft fuselage at X_{CG} 1307 and Z_{CG} 500 through a titanium alloy attachment fitting and runs spanwise of the vertical stabilizer along chordline 9.8%. Flight loads reacting through the fin attachment points may cause fatigue damage to the front spar in the fuselage attachment region. Wind gust loads causing bending moments on the vertical fin may cause damage at other points along the front spar.

DEFECTS: Cracks between fasteners at the spar-to-fuselage attach fitting; also, edge cracks and fastener hole cracks near spar to rib attach areas above fuselage attach region.

ACCESS: Remove vertical lower leading edge fairings. Some portions of front spar may be sandwiched between fin-fuselage attach fitting and vertical stabilizer skin panels.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3C) for V.S.L.E./fus attach; eddy current (Para. 1.5.4.4) (leading edge removed) or radiography (Para. 1.5.6.2) (for sandwiched areas or inspection with leading edge intact).
Backup: Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) except for main attach bolt holes for which eddy current bolt hole (Para. 1.5.4.3) should be used.

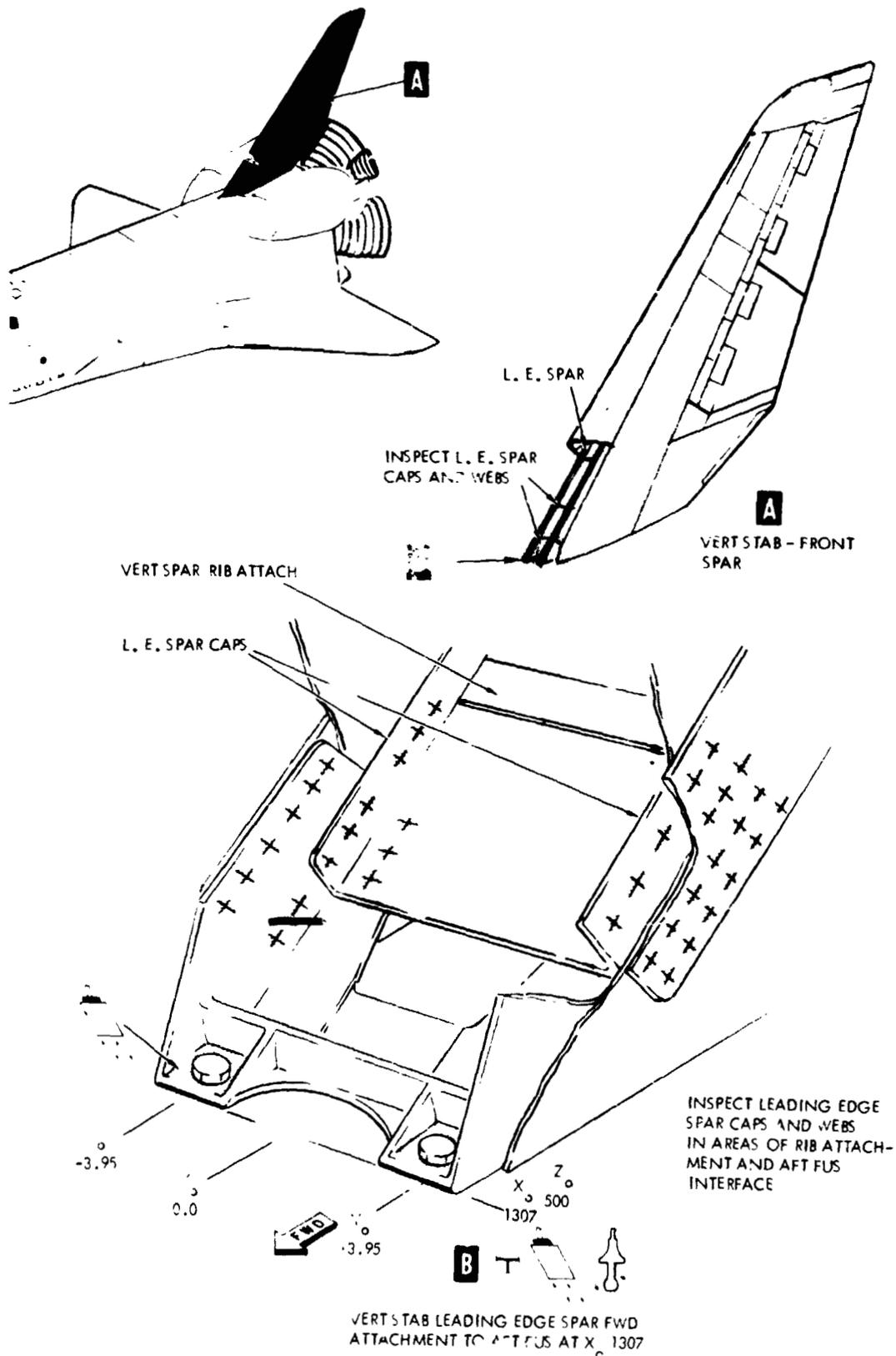


Figure 6-1. Vertical Stabilizer Front Spar Caps

PROCEDURE NO: 6-702, FIGURE 6-2
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER
ZONE 7

TYPE INSPECTION:
(X) POSTFLIGHT

SUBASSEMBLY: VERT FIN AFT SPAR

DRAWING(S): VL70-005107, FAIRCHILD 170G410000

COMPONENT AREA DESCRIPTION: VERT STAB-FUS AFT ATTACH FITTING. The safe life designed structure whereby the vertical stabilizer is attached to the aft fuselage V.S. support frame is made of 2124-T851 aluminum alloy machined plate and has a zinc chromate primer and Supercorapon 515-700 paint surface finish. During entry glide ($M = 0.9$), the fitting receives high tensile, compressive and shear loads. G-forces during ascent, lateral wind gusts and maneuvers in atmospheric flight may also help to induce damage in the fitting. The attach plate is located at $X_0 = 1426$, $Z_0 = 516$ at the base of the V.S. rear spar.

(Coordinate with inspection of main fin support spar, aft fus)

DEFECTS: Horizontal cracks emanating from bolt holes in the clevis attach areas; horizontal cracks at fastener holes near adjacent ribs.

ACCESS: (Not clear). For eddy current bolt hole insp, clevis bolt must be removed - only one at a time.

NDT TECHNIQUES: Primary: Eddy current surface probe (Para. 1.5.4.4) for lug fillet inspection; eddy current bolt hole (Para. 1.5.4.3) with clevis bolt removed for bolt hole insp.
Backup: Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9).

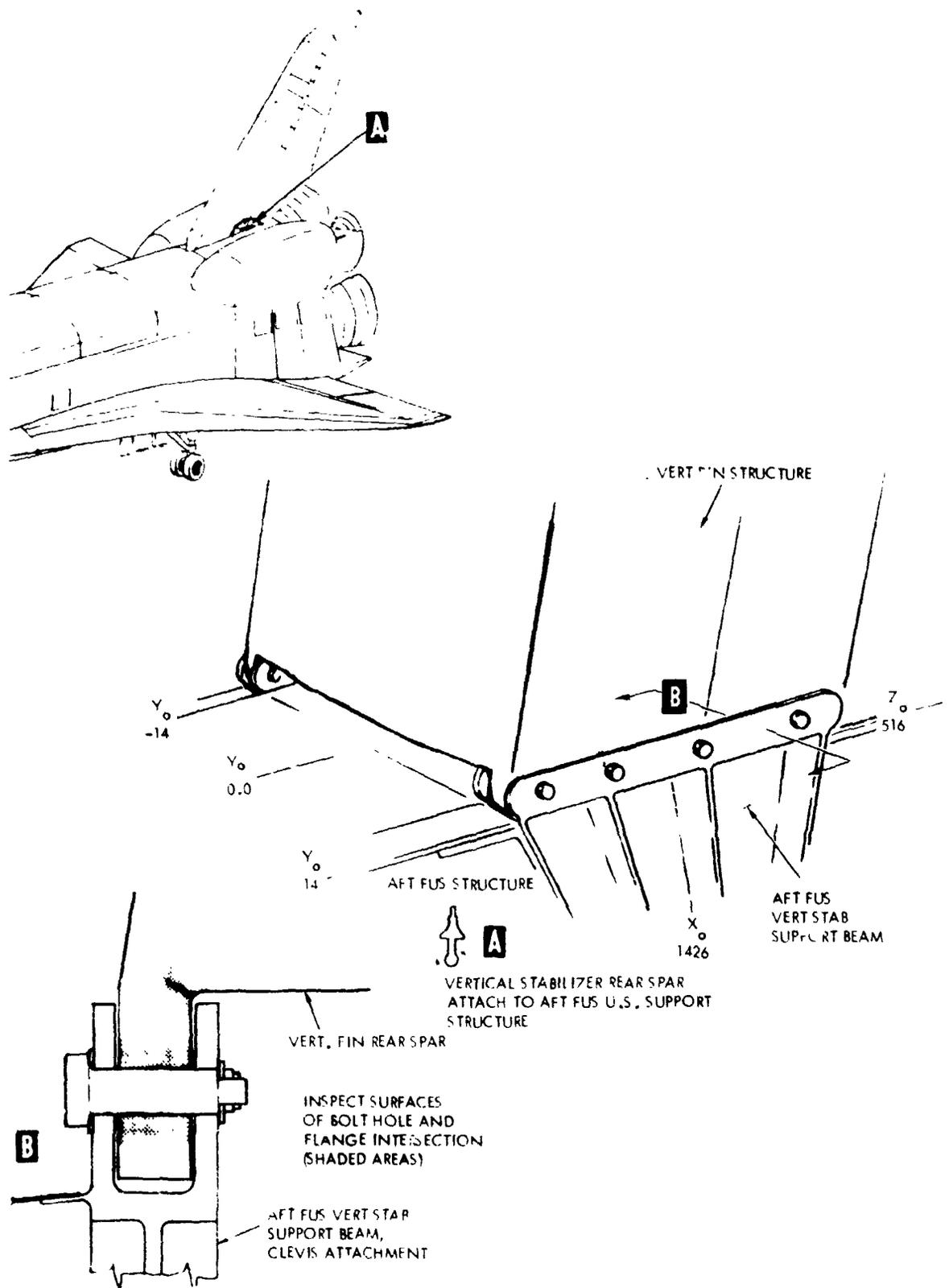


Figure 6-2. Vertical Stabilizer/Fuselage Aft Attachment

PROCEDURE NO: 6-703, FIGURE 6-3
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER, TYPE INSPECTION:
ZONE 7 (X) POSTFLIGHT
SUBASSEMBLY: VERTICAL FIN
DRAWING(S): 170G400000

COMPONENT / AREA DESCRIPTION: VERTICAL STABILIZER SKINS: The V.S. skin panels are made of 2024-T86 aluminum alloy formed sheet stiffened by riveted hat sections. They have a zinc chromate primer and a double coat of Supercorapon 515-700 exterior surface finish. In addition, the exterior surface is completely covered by adhesively bonded LRSI/TPS panels. The interior surfaces have a zinc chromate primer and single coat of Supercorapon 515-700 finish. Tensile and shear loads induced in the skin at certain locations by a spectrum of flight loads may produce fatigue damage.

DEFECTS: Through-cracks in skin panels along the base of the vertical fin at lwr skin splices and in regions near rudder lower edge or joint discontinuities.

ACCESS: TPS panels prevent direct access from the outside. Limited access to vertical fin interior. Local TPS panels must be removed to apply backup inspection.

NDT TECHNIQUES: Primary: X-ray (Para. 1.5.6.2) for gross cracks in skin panels (if TPS panels are removed, visual, eddy current, and /or penetrant NDE can be applied).
Backup: Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) or eddy current (Para. 1.5.4.4).

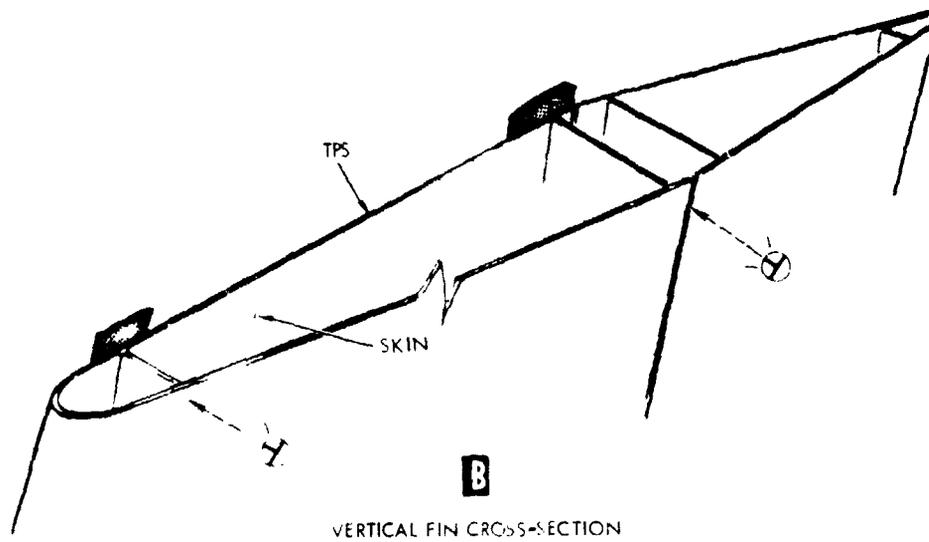
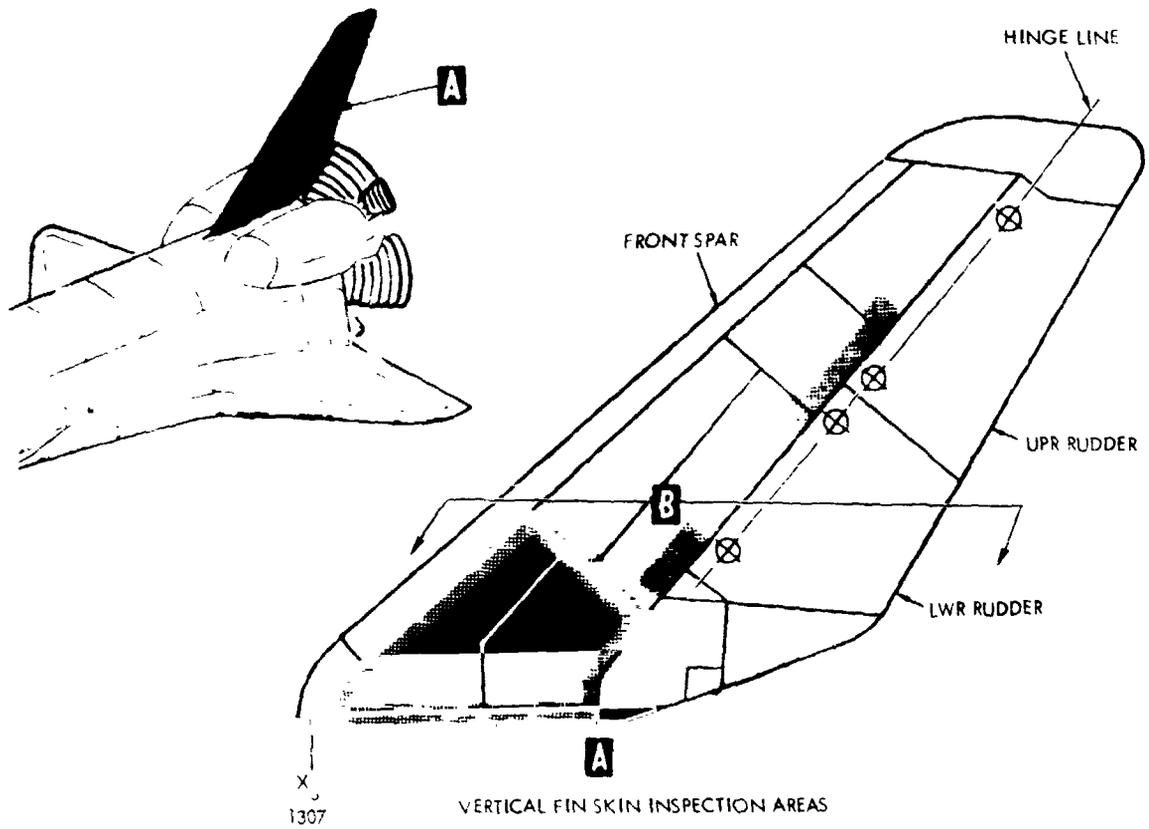


Figure 6-3. Vertical Stabilizer Skins

PROCEDURE NO.: 6-704, FIGURE 6-4
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER,
ZONE 7

TYPE INSPECTION:
(X) POSTFLIGHT

SUBASSEMBLY: VERT STAB REAR SPAR

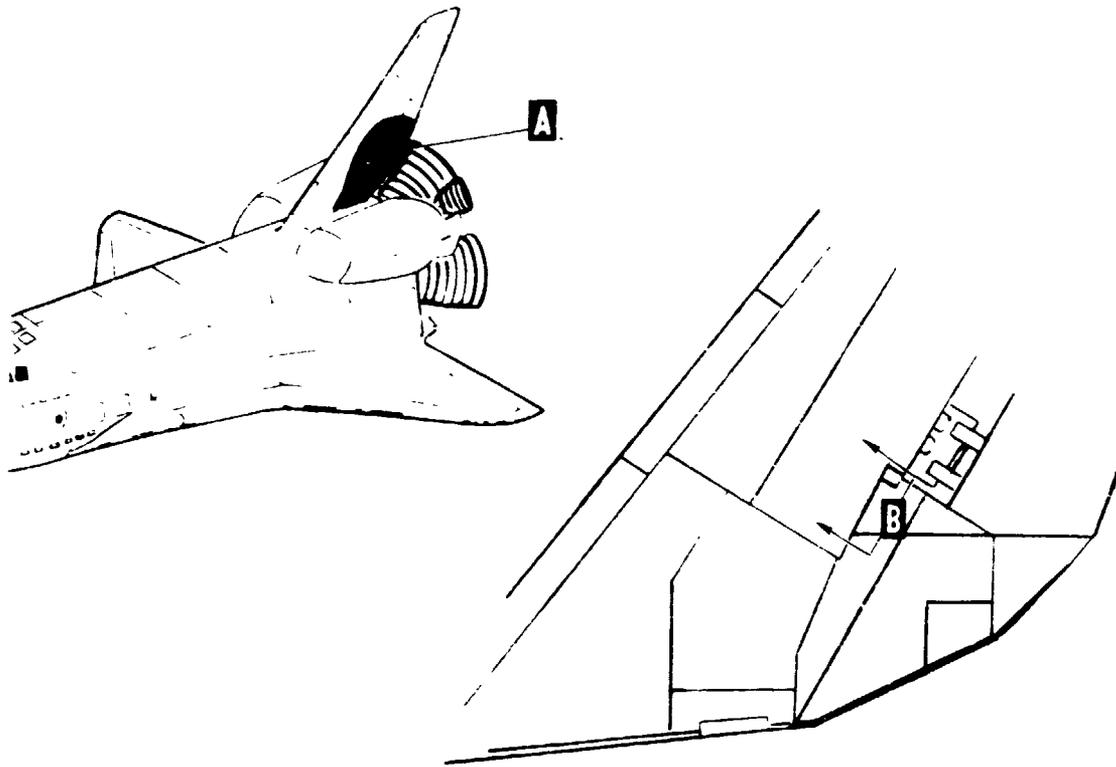
DRAWING(S): VL70-000037, VL70-000044

COMPONENT/AREA DESCRIPTION: VERTICAL STABILIZER REAR SPAR AT RUDDER LOWER FORWARD EDGE. The rear spar, restrained by a rib at the base of the lower rudder, experiences torsional loads at this location due to rudder deployment during cross-range and cruise flight. Damage may potentially occur to the 2024 or 2124 aluminum alloy spar caps and cap-to-web attachments. The structure is finished with zinc chromate primer and Supercorapon 515-700 paint.

DEFECTS: Cracks in the spar/rib/skin interfacial attachment holes or edges, at or near the interfaces of these components.

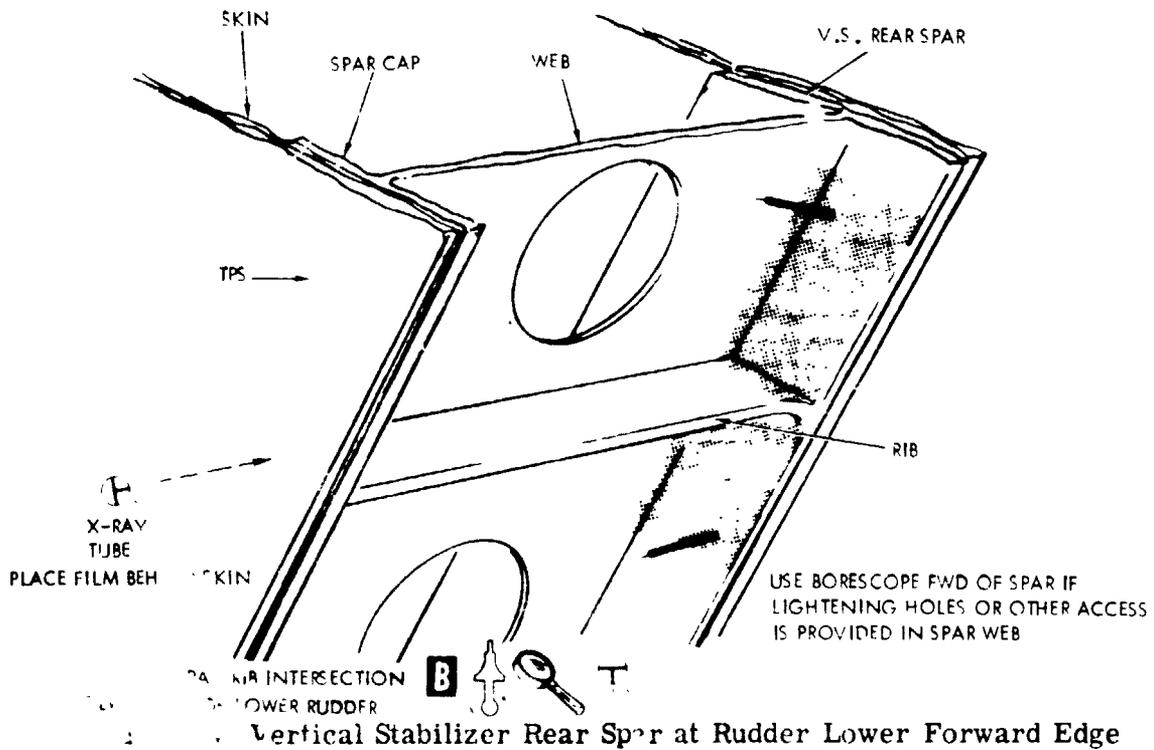
ACCESS: Remove the local lower rudder thermal seal as necessary and spar access panels. Some access is also obtained through the drag chute compartment with the chute removed.

NDT TECHNIQUES: Primary: Eddy current surface probe (Para. 1.5.4.4) and optical borescope (Para. 1.5.1.3). X-ray radiography (Para. 1.5.6.2) may be used for inaccessible sandwich structure.
Backup: Fluorescent penetrant (Para. 1.5.2.1, Fig. i-9).



A

VERTICAL STABILIZER, LOWER AREA



Vertical Stabilizer Rear Spar at Rudder Lower Forward Edge

PROCEDURE NO: 6-705, FIGURE 6-5
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER,
ZONE 7

TYPE INSPECTION:
(X) POSTFLIGHT

SUBASSEMBLY: VERT STAB REAR SPAR

DRAWING(S): FAIRCHILD 170G400000, 170G411000

COMPONENT/AREA DESCRIPTION: RUDDER/SPEED BRAKE ACTUATOR AND HINGE/V.S. REAR SPAR ATTACH POINT. There are at least one actuator and two hinges for each of two rudder sections located along the vertical fin rear spar at Z_o 616, Z_o 666, Z_o 684, Z_o 702, Z_o 711 and Z_o 778. The rear spar attachments support the rudder reaction loads when the actuator deploys the rudder during cross-range and cruise flight. The materials are 2024 and 2124 aluminum finished with zinc chromate primer and Supercorapon 515-700 paint. Actuator attachments and local V.S. rear spar structure should be inspected for fatigue damage.

DEFECTS: Cracks may occur in actuator and hinge attachment fittings and in adjacent vertical fin rear spar structure.

ACCESS: Access to the attach fittings and adjacent vertical fin rear spar structure is attained by removing the Rudder/Speed Brake Actuator panels on the vertical tail. Additional inspection of actuator attachments (adjacent l.e. structure) can be made when the rudder thermal seals are removed. Remove hinge/rear spar bolts for hole inspection.

NDT TECHNIQUES: Primary: Eddy current surface probe (Para. 1.5.4.4) and bolt-hole probe (Para. 1.5.4.3).
Backup: Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9).

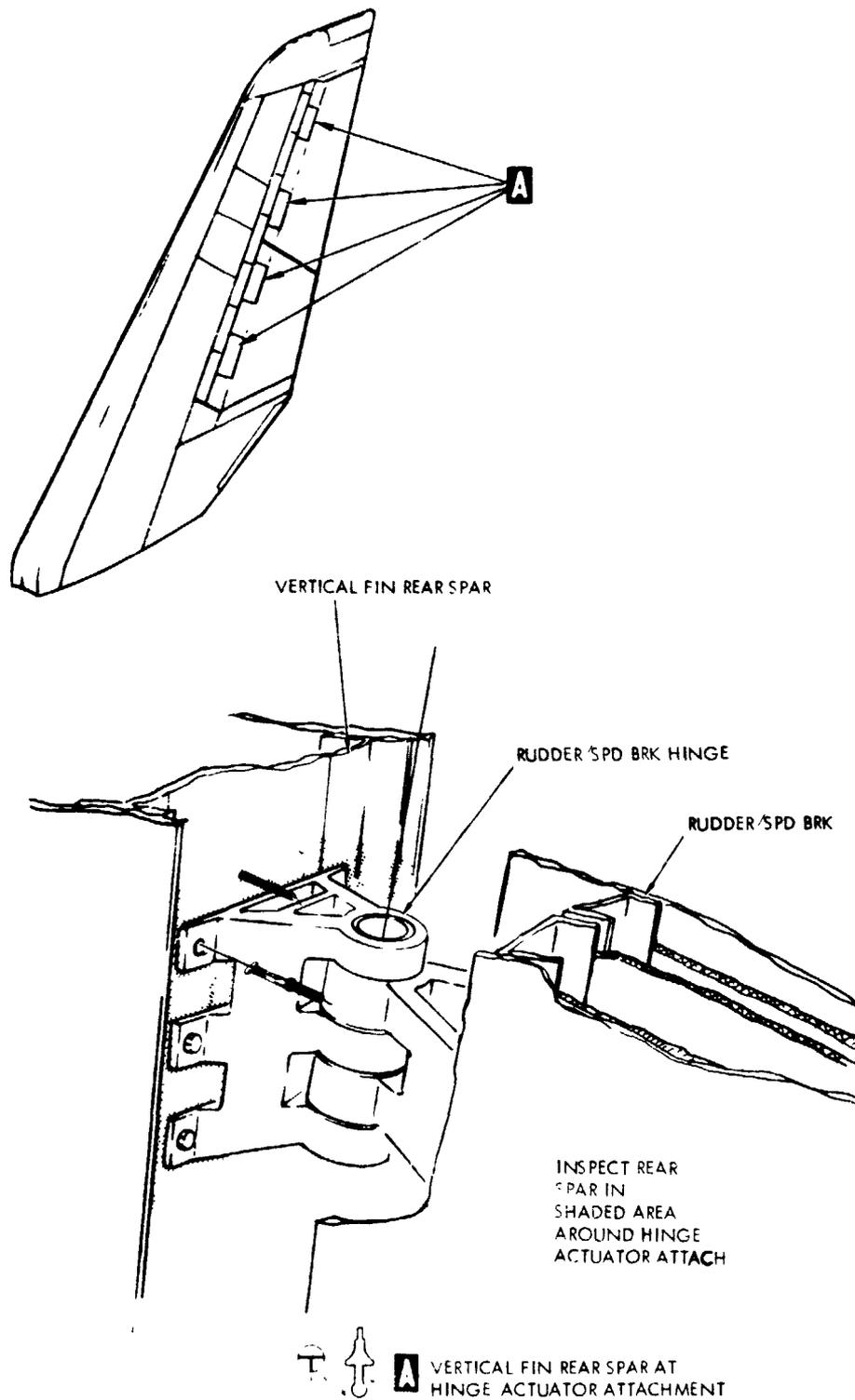


Figure 6-5. Rudder/Speed Brake Actuator and Hinge/Vertical Stabilizer Rear Spar Attach

PROCEDURE NO: 6-706, FIGURE 6-6
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER,
ZONE 7
SUBASSEMBLY: RUDDER/SPD BRAKE HINGES
DRAWING(S): VL72-001034, VL72-000104 'A'
FAIRCHILD 170G400000, 170G411000

TYPE INSPECTION:
(X) POSTFLIGHT

COMPONENT/AREA DESCRIPTION: RUDDER/SPEED BRAKE ACTUATOR/HINGE.

Each of the two rudder sections contains two actuator and hinge assemblies attached to the vertical fin rear spar and the rudder front spar along the vertical stabilizer plane of symmetry ($Y_{CG} 0.0$) and 60% chord line. The actuators are connected by a common drive shaft which is actuated by a hydraulic power drive unit at the base of the lower rudder. Locations of the upper actuator/hinge assemblies are $X_{CG} 1620$ and $Z_{CG} 760$, $X_{CG} 1575$ and $Z_{CG} 696$. The lower rudder section assemblies are at $X_{CG} 1550$ and $Z_{CG} 662$; $X_{CG} 1515$ and $Z_{CG} 610$. The hinges are made of 2124-T851 aluminum alloy and the adjacent spar structure is 2024 aluminum alloy having a zinc chromate primer and Supercorapon 515-700 paint surface finish. The material of the hinge actuators is (TBD). The hinge/actuator assemblies and attachments to the fin and rudder spars should be inspected because of reaction loads placed on the components when the rudder/speed brakes are deployed into the air stream.

DEFECTS: Possible cracks in the hinge and actuator assemblies or adjacent vertical stabilizer rear spar or rudder front spar structure. The actuator drive shaft connecting the actuators should be visually inspected.

ACCESS: Remove local rudder/speed brake seal panels at the hinge/actuator locations and the rudder/speed brake actuator attach access panels aft of each location.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3 B&C) for hinge lugs and hinge/spar attach flanges; eddy current (Para. 1.5.4.4) or radiography (Para. 1.5.6.2) for adjacent attached structure.

PROCEDURE NO: 6-706, FIGURE 6-6 (continued)

Backup: Eddy current bolt hole (Para. 1.5.4.2) and
fluorescent penetrant (Para. 1.5.2.1, Fig. 1.9).

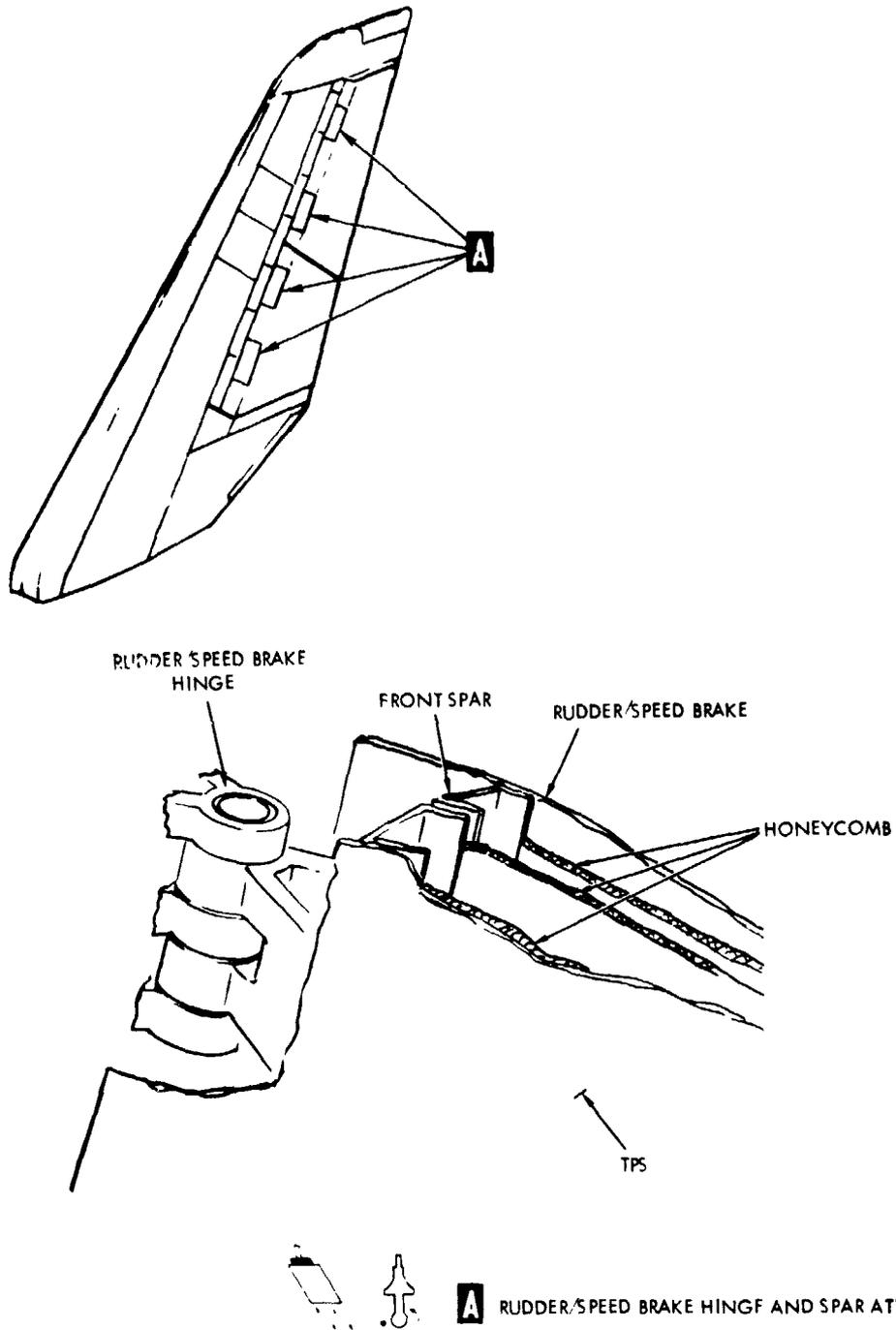
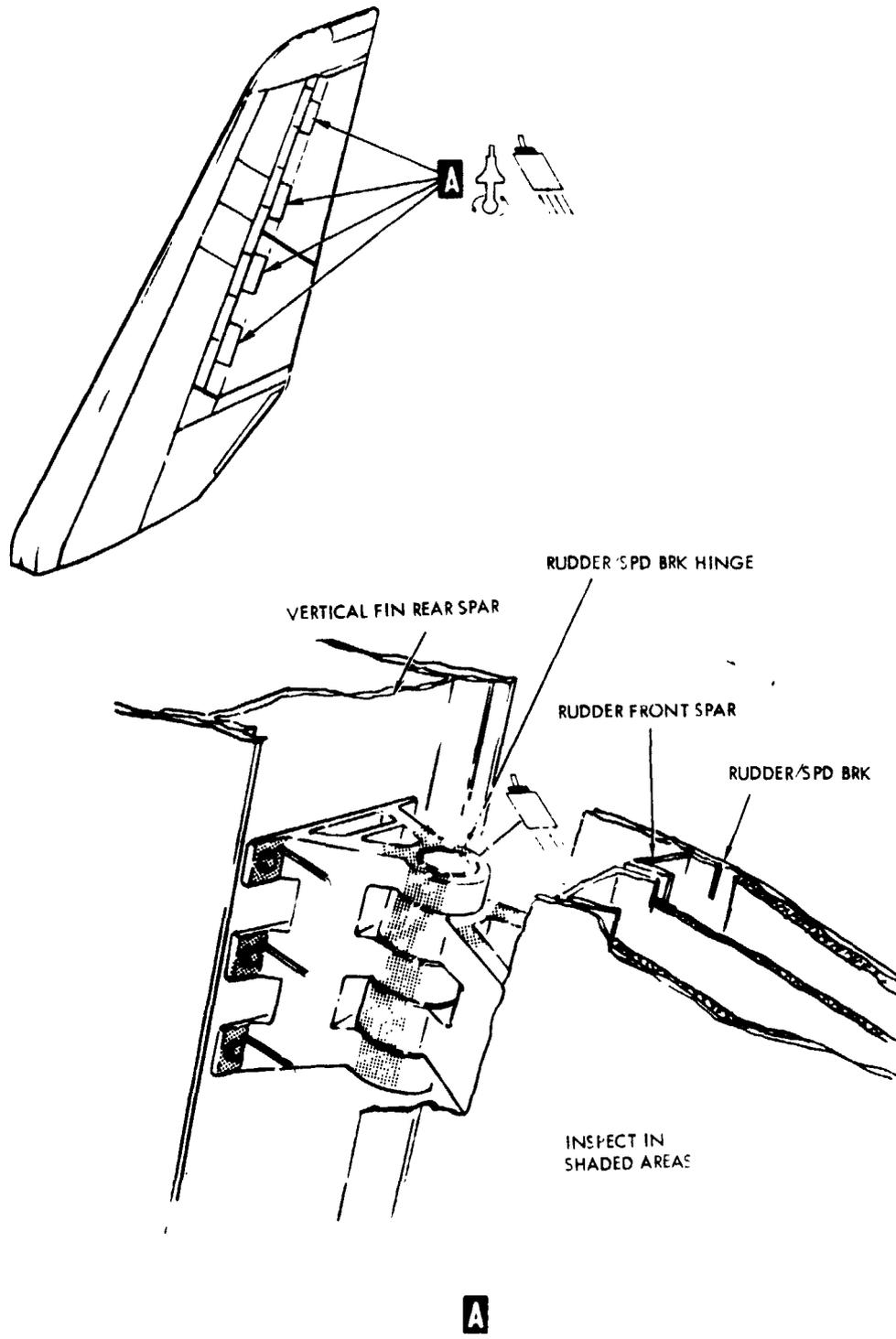


Figure 6-6. Rudder Speed Brake Actuator/Hinge (Sheet 1 of 2)



RUDDER 'SPEED BRAKE HINGE FITTINGS, TYPICAL

Figure 6-6. Rudder/Speed Brake Actuator/Hinge (Sheet 2 of 2)

PROCEDURE NO: 6-707, FIGURE 6-7
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER,
ZONE 7
SUBASSEMBLY: RUDDER/SPEED BRAKE
DRAWING(S): 170G411000 (FAIRCHILD)
(Ref. Fig. 1.8.3) 73MA5769

TYPE INSPECTION:

(X) POSTFLIGHT

COMPONENT/AREA DESCRIPTION: RUDDER FRONT SPAR. The rudder front spar, made of 2024-T3511 aluminum alloy forging and having a zinc chromate primer and Supercorapon 515-700 paint surface finish, is subject to fatigue damage in the attachment areas to rudder hinges and actuators and closeout ribs. The actuators deploy the rudders and speed brakes into the airstream to affect yaw or speed reduction, respectively. The areas may be highly stressed during atmospheric flight maneuvers, particularly in the approach and landing sequence in which high shear and compressive loads are applied to the spar. The safe-life designed spar comprises the forward closure of the rudder box, upper and lower halves.

DEFECTS: Through-cracks between fastener holes where attachments are made to hinge and actuator fittings and honeycomb closeout panels.

ACCESS: (Not well defined). Rudder hinge opening thermal seals must be withdrawn. Access to aft side of spar may be limited. Access is through lightening/access holes in fwd spar.

NDT TECHNIQUES: Primary: Optical borescope (Para. 1.5.1.3) or radiography (Para. 1.5.6.2) (if access permits placement of film behind spar).
Backup: Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9).

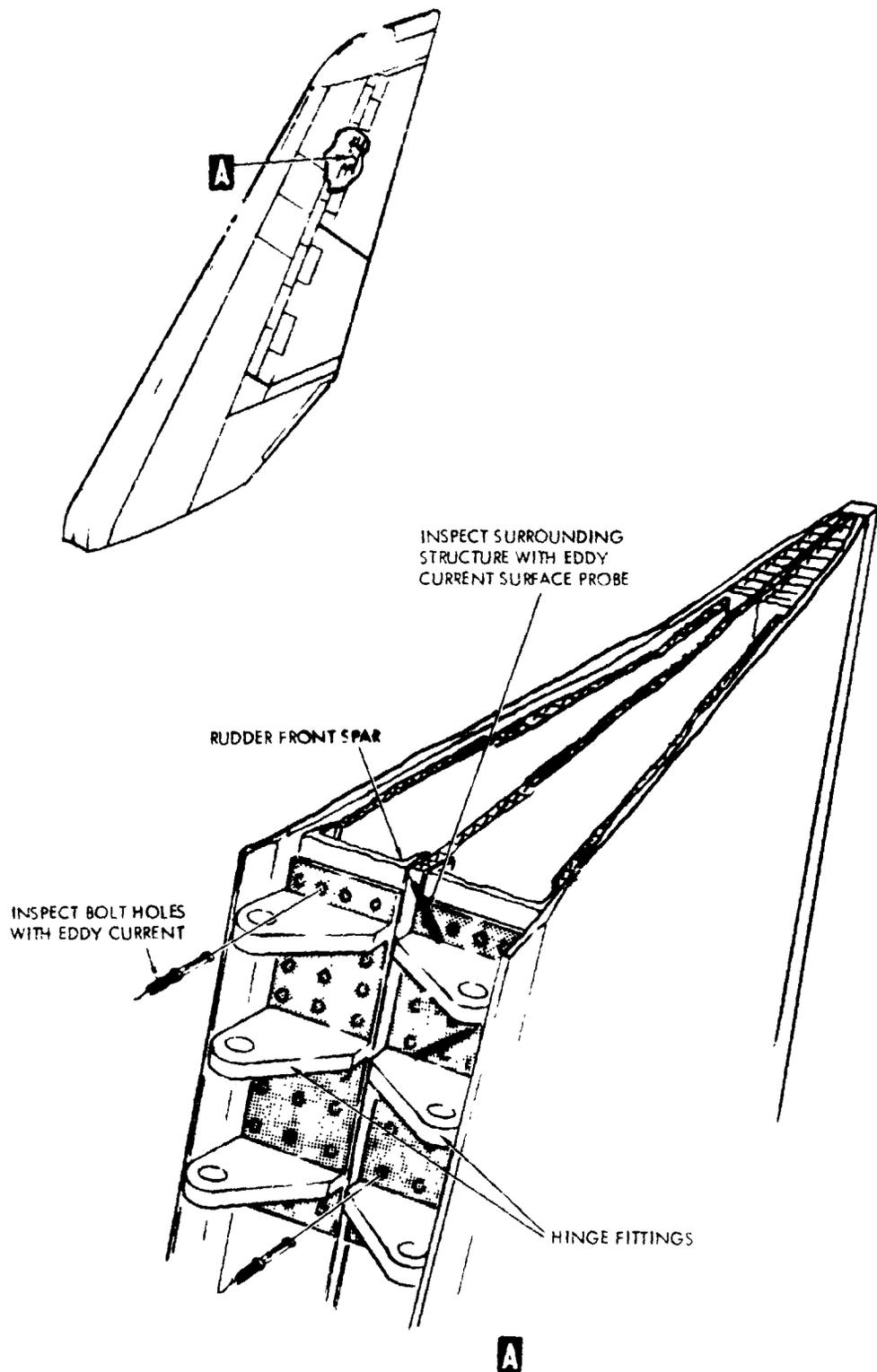


Figure 6-7. Rudder Front Spar

PROCEDURE NO: 6-708, FIGURE 6-8
MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER,
ZONE 7
SUBASSEMBLY: RUDDER/SPEED BRAKE
DRAWING(S): 170G411000

TYPE INSPECTION:
(X) POSTFLIGHT

COMPONENT/AREA DESCRIPTION: RUDDER/SPEED BRAKE REAR SPAR. The rudder rear spar is made of 2024-T86 aluminum alloy formed sheet and has a zinc chromate primer and one (1) coat of Supercorapon 515-700 finish. The rear spar closes out the rudder box assembly and supports the full-depth honeycomb rudder trailing edge. Aerodynamic loads are imposed on the rear spar when the rudder or speed brakes are deployed in atmospheric flight, potentially causing damage in some locations.

DEFECTS: Cracks at rudder rear spar cap attachments to skin and rudder full-depth honeycomb trailing edge, particularly in vicinity of upper and lower extremities of rudder.

ACCESS: Deploy rudder right or left and remove rudder thermal seals as necessary. Access for rear spar inspection is through rudder fwd spar access holes.

NDT TECHNIQUES: Primary: Optical Borescope (Para. 1.5.1.3) and X-ray Radiography (Para. 1.5.6.2).
Backup: TBD.

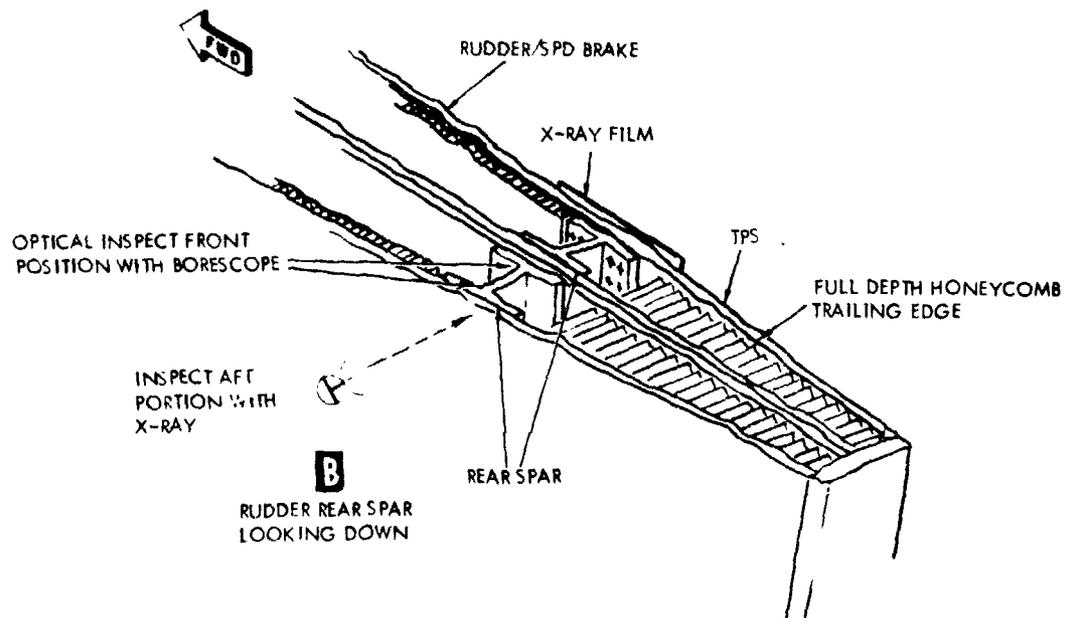
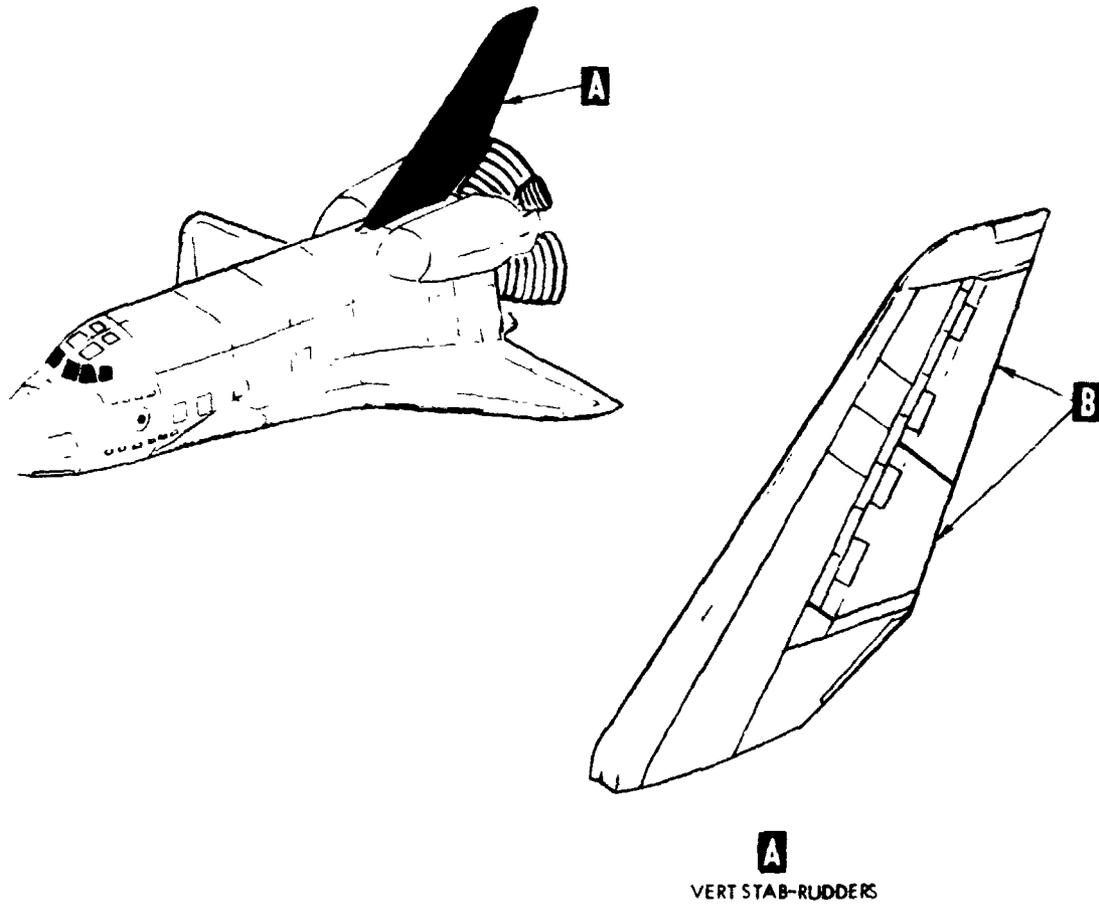


Figure 6-8. Rudder Rear Spar

PROCEDURE NO: 6-709, FIGURE 6-9

TYPE INSPECTION:

MAJOR ASSEMBLY: ORBITER, VERTICAL STABILIZER,
ZONE 7

(X) POSTFLIGHT

DRAWING(S): FAIRCHILD: 170GA11000, 170G400000

COMPONENT/AREA DESCRIPTION: RUDDER/SPEED BRAKE HONEYCOMB SKIN

PANELS. The rudder/speed brake is a split, two-section assembly hinged to the vert. stab. rear spar along the 60% chord line. These yaw/speed control surfaces consist of conventional stiffened skins with ribs and spars for primary load carrying members. The skin panels are made of bonded 2024-T86 aluminum alloy facesheets and aluminum honeycomb core. Repeated exposure to vibroacoustic, aerodynamic and thermomechanical loads may cause core-to-facesheet separations in the honeycomb panels. In addition, residual reactive gases and water vapor inside the honeycomb core may cause corrosion damage to the aluminum core walls.

DEFECTS: Core-to-facesheet disbonds or separations; core damage due to corrosion vapors and/or water (ice) damage.

ACCESS: The rudder/speed brake structure is accessible from suitable work platforms. X-ray inspection can be accomplished as is. Sonic or thermographic inspection requires the removal of TPS panels and thorough cleaning of facesheet outer surface.

NDT TECHNIQUES: Primary: X-ray (Para. 1.5.6.2) for core damage and water entrapment; sonic (Para. 1.5.5.6) or thermographic (Para. 1.5.8.2) for core-to-facesheet separations.

Backup: Mechanical pull test for disbonds greater than TBD inches diameter.

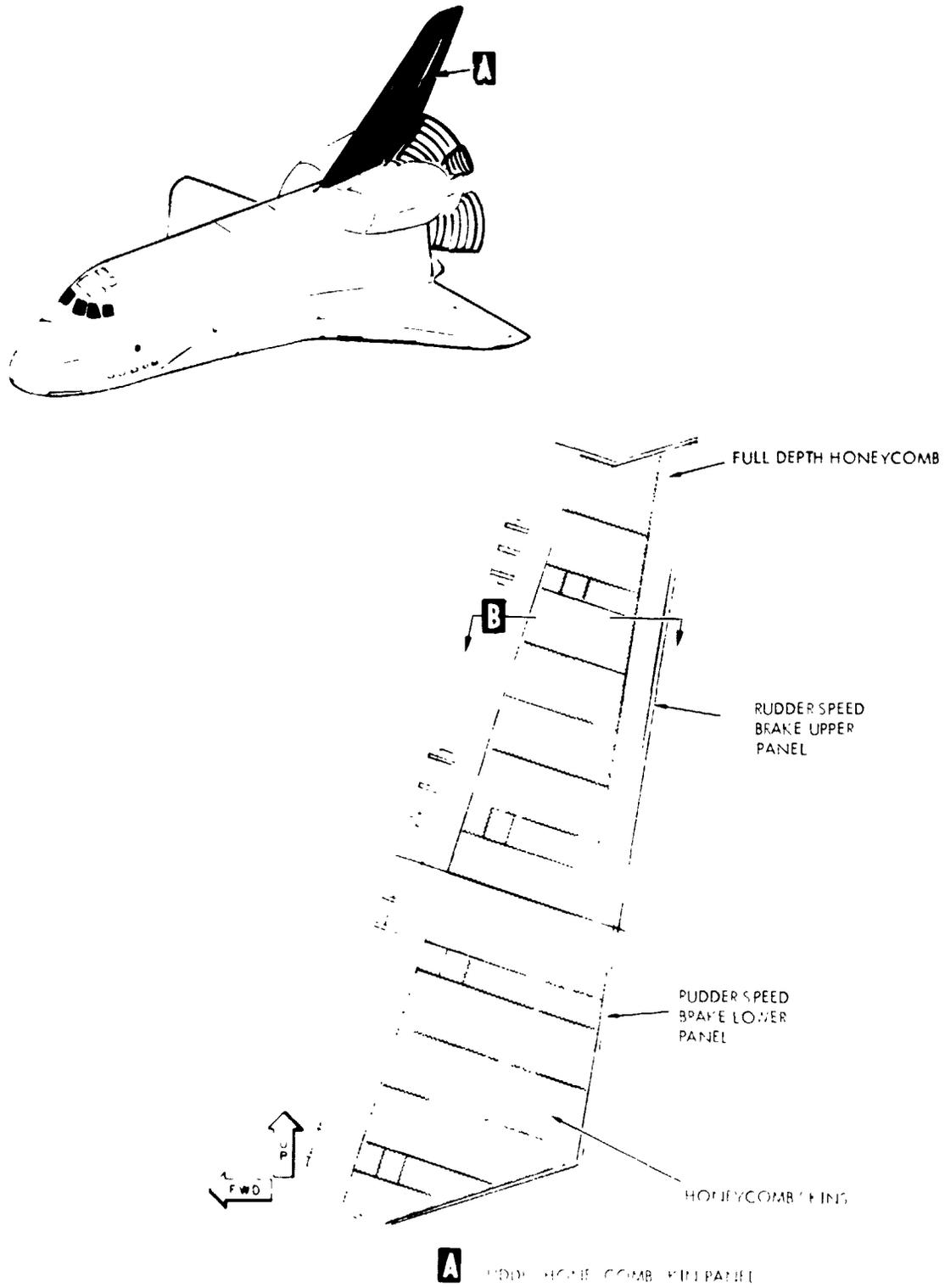


Figure 6-9. Rudder/Speed Brake Honeycomb Skin Panels (Sheet 1 of 2)

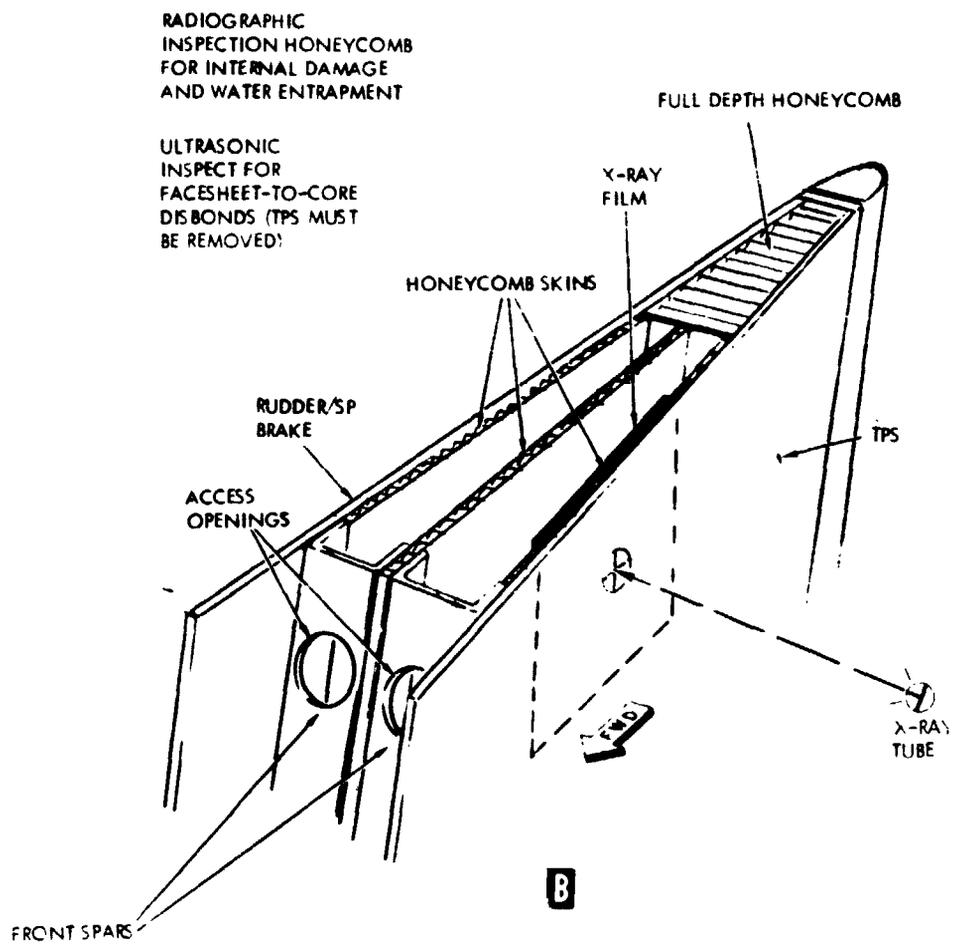


Figure 6-9. Rudder/Speed Brake Honeycomb Skin Panels (Sheet 2 of 2)

SECTION 7. EXTERNAL TANK STRUCTURE

This section contains the preflight NDE requirements for the ET/Orbiter forward and aft attach structure and the ET/SRB forward and aft attach structure which may receive damage due to abnormal conditions prior to launch.

SECTION 7
TABLE OF CONTENTS

<u>Procedure No.</u>	<u>Title</u>	<u>Page</u>
7-801	ET/Orbiter Forward Attach Fitting	7-1
7-802	Forward SRB Attachment Thrust Longerons	7-2
7-803	Forward SRB/ET Attachment Fitting	7-4
7-804	Aft ET/ORB Attach Fittings	7-6
7-805	Aft ET/ORB Attach Trusses	7-8
7-806	ET/SRB Aft Attach Fittings	7-10

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SECTION 7
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
7-1	ET/Orbiter Forward Attachment Fitting and Thrust Longerons	7-3
7-2	Forward SRB/ET Attachment Fitting	7-5
7-3	Aft ET/Orbiter Attach Fittings	7-7
7-4	Aft ET/Orbiter Attach Trusses	7-9
7-5	ET/SRB Aft Attach Fittings	7-11

PROCEDURE NO: 7-801, FIGURE 7-1
MAJOR ASSEMBLY: EXTERNAL TANK, ZONE 8
SUBASSEMBLY: FORWARD ATTACHMENT
INTERFACE

TYPE INSPECTION:
(X) PREFLIGHT

DRAWING(S): VL72-000103A, VL78-000018, VL78-000024

COMPONENT/AREA DESCRIPTION: ET/ORBITER FORWARD ATTACHMENT

FITTING. There are two fittings located on the ET at X_f 1078, Z_f 558 and $Y_f \pm 46.5$. They are machined from Ti-5Al-2.5Sn titanium. The fitting reacts intervehicle loads between ET and Orbiter resulting from static and G-loads, vibro-acoustics, aerodynamics, wind buffeting and maneuver loads. Since the ET is not recovered after launch for reuse, flight damage is of no concern (for refurbishment considerations). However, sustained static loads and wind exposure for an excessive time on the launch pad may result in fatigue damage and the fitting should be inspected prior to launch.

DEFECTS: Cracks in the fitting lug attachment hole and in the fillet where the lug blends into the base of the fitting.

ACCESS: Access is attained by use of platforms or booms while the Shuttle is in the vertical launch attitude.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3 B) for the lug attachment hole and fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) for fillets and general areas.

Backup: Eddy current bolt hole (Para. 1.5.4.3) or penetrant (Para. 1.5.2.1, Fig. 1-9) for lug bolt-hole area.

PROCEDURE NO: 7-802, FIGURE 7-1
MAJOR ASSEMBLY: EXTERNAL TANK, ZONE 8
SUBASSEMBLY: FWD SRB/ET ATTACH
INTERFACE
DRAWING(S): VL78-000024, VL72-00103A

TYPE INSPECTION:

(X) PREFLIGHT

COMPONENT/AREA DESCRIPTION: FWD SRB ATTACHMENT THRUST LONGERON.

This safe-life 7075-T73 aluminum alloy forging receives the SRB thrust loads and, via the ET/SRB attach fitting at station X_f 947, transfers them into the ET intertank frames and skin. The longeron experiences high tensile loads during thrust buildup and acceleration to maximum "G" loads. Since the ET is not recovered for reuse after a launch cycle, flight damage is of no concern for refurbishment. However, static fatigue and corrosion damage may occur to the mated Shuttle vehicles during mating or while the vehicle rests on the launch pad. In the event that the Shuttle remains mated on the launch pad for an excessive time or experiences high pre-launch wind gusts, the longeron and ET/SRB attachment fitting should be inspected.

DEFECTS: Transverse cracks in the longeron radiating from the ET/SRB attachment boss, and transverse cracks at fastener holes at frame attachment stations.

ACCESS: The longeron is accessible from outside the ET by the use of booms and from inside the ET intertank area. Enter the ET through the intertank access opening.

NDT TECHNIQUES: Primary: Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) for ET/SRB attach area. Eddy current (Para. 1.5.4.4) or radiography (Para. 1.5.6.2) for frame-longeron attach areas.
Backup: Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-4) for frame-longeron areas.

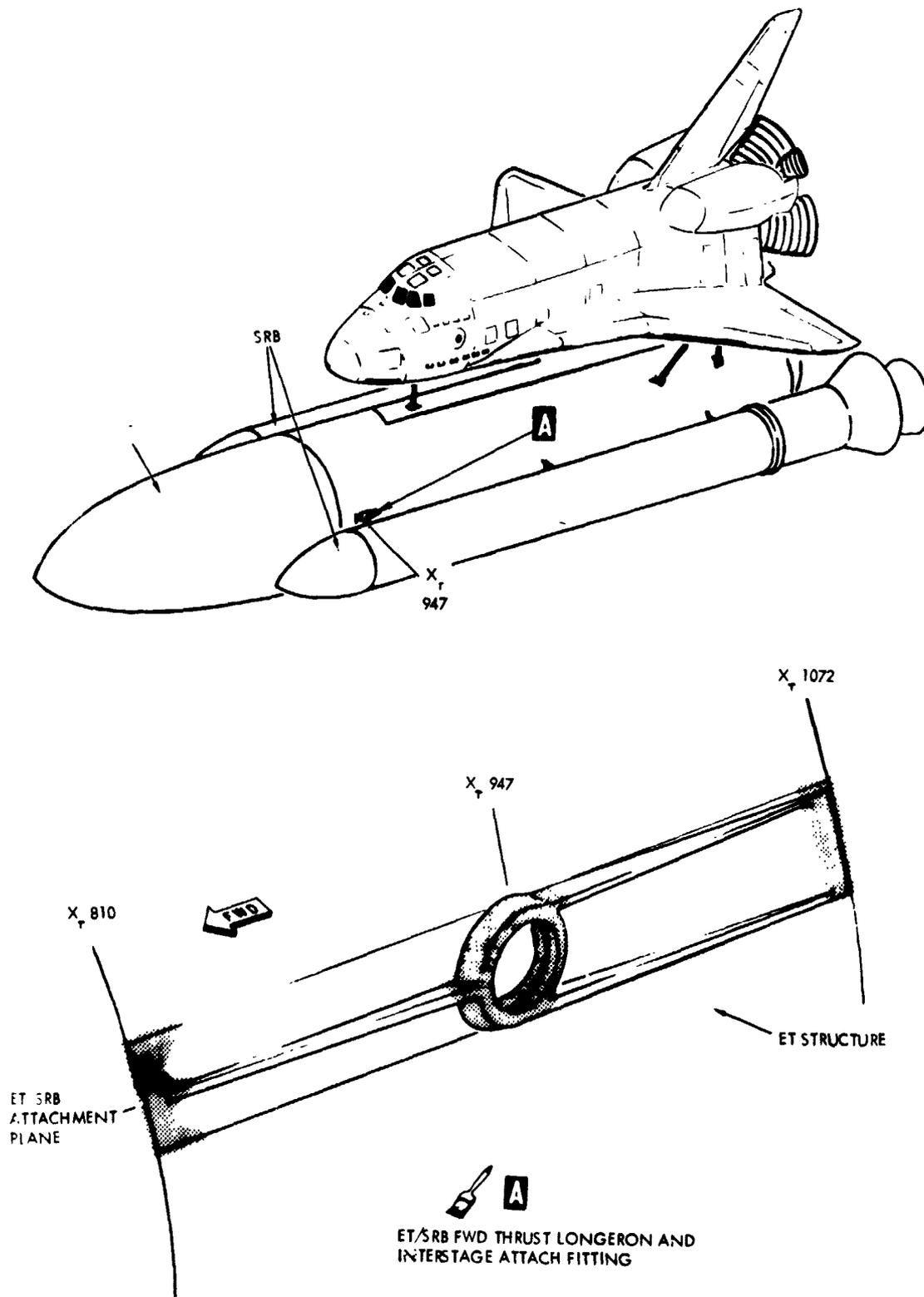


Figure 7-1. ET/Orbiter Forward Attachment Fitting and Thrust Longeron

PROCEDURE NO: 7-803, FIGURE 7-2 TYPE INSPECTION:
MAJOR ASSEMBLY: EXTERNAL TANK, ZONE 8 (X) PREFLIGHT
SUBASSEMBLY: FWD SRB/EOHT ATTACH INTERFACE
DRAWING(S): V178-000024, VL72-000103A
COMPONENT/AREA DESCRIPTION: FWD SRB/ET ATTACHMENT FITTING. This fitting mates with a similar fitting on the SRB at two locations, one on each side of the ET fuselage. These fittings are located at ET coordinates, X_f 947, Y_f \pm 166 and Z_f 400, along the stack reference plane. The fittings react G-loads, vibro-acoustics, wind buffeting, aerodynamics and ascent maneuver loads. Since the ET is not recovered for reuse, flight damage is of no concern (for refurbishment purposes). However, if the Shuttle remains on the launch pad for an excessive time experiencing adverse wind conditions and high salt content atmospheres, the fittings should be inspected prior to launch for damage.

DEFECTS: Cracks in or near the fitting attachment surfaces due to wind gust damage or high sustained hook-up loads combined with salt laden atmosphere.

ACCESS: Access is readily attained by the use of booms while the Shuttle is in the vertical launch attitude.

NDT TECHNIQUES: Primary: Ultrasonic shear (Para. 1.5.5.3 B or A) or longitudinal wave and fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9).
 Backup: TBD.

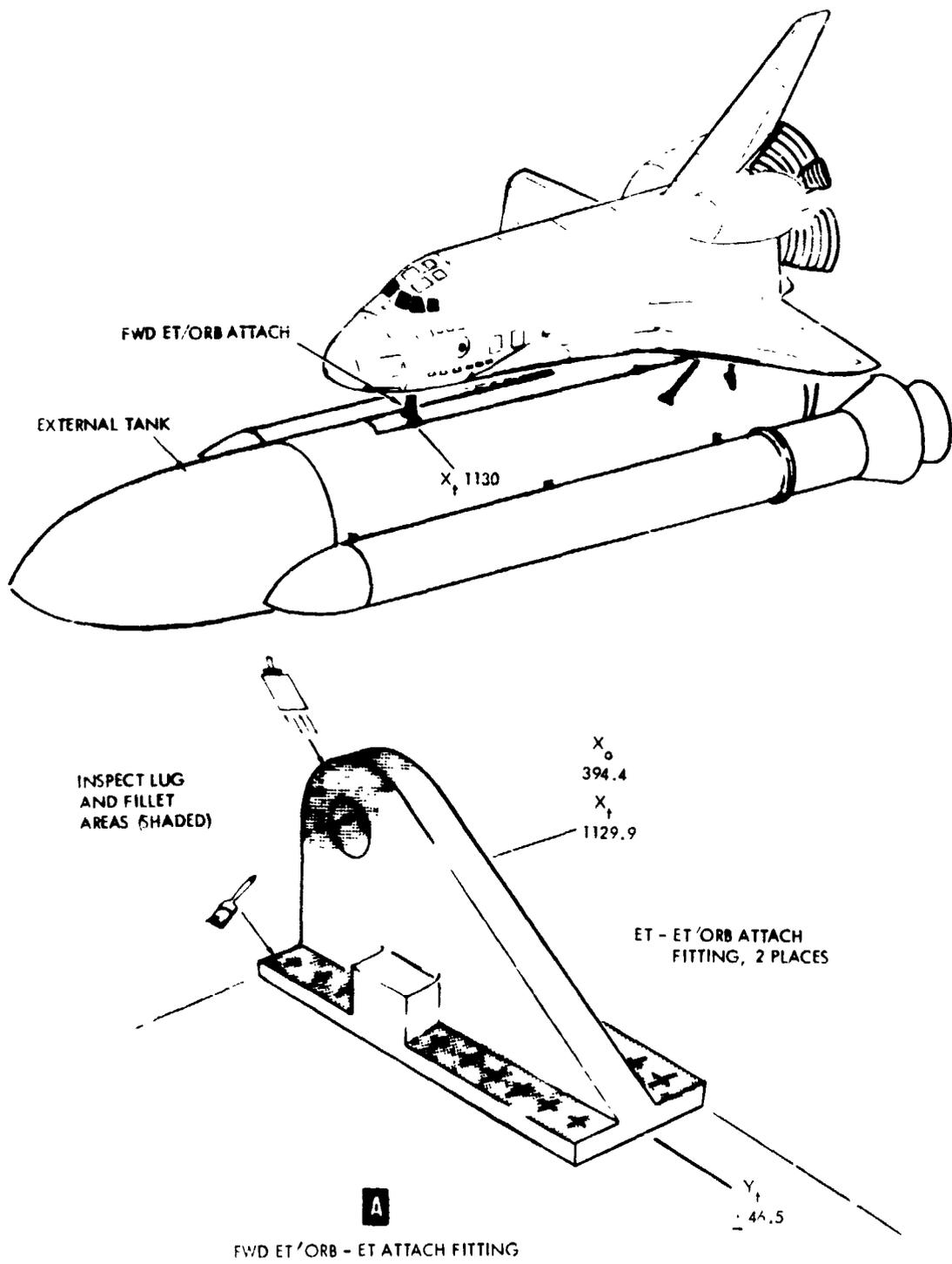


Figure 7-2. Forward SRB/ET Attachment Fitting

PROCEDURE ID: 7-804, FIGURE 7-3
MAJOR ASSEMBLY: EXTERNAL TANK, ZONE 8
SUBASSEMBLY: AFT ET/ORB INTERFACE
DRAWING(S): VL72-000103A, VL72-000009, VL78-000024

TYPE INSPECTION:
(X) PREFLIGHT

COMPONENT/AREA DESCRIPTION: AFT ET/ORB ATTACH FITTINGS. The external tank contains six fittings along the aft ring frame at X_f 2058 and the support longeron extending from X_f 1959 to X_f 2058, where truss attachments are made to the Orbiter aft attach trusses. These titanium fittings contain clevis attachments to the trusses and have flange attachments to the ET frame structure. The fittings are subjected to tensile, compressive and shear loadings due to G-forces and intervehicular flight loads during lift-off and ascent. The fittings must be free of significant defects during this crucial period. Sustained static fit-up loads and wind gusts while on the launch pad may produce damage in the lug or flange attach areas and should be inspected prior to liftoff in the event of high winds and/or excessive launch hold.

DEFECTS: Radial cracks in the clevis lug bolt holes and cracks in the lug-to-base fillets.

ACCESS: Accessible from outside ET and Orbiter. Requires boom and work platform for proper elevation.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3 B) for lug bolt hole, fluorescent (Para. 1.5.2.1, Fig. 1-9) for other areas.
Backup: Eddy current bolt hole (Para. 1.5.4.3) for lug bolt hole.

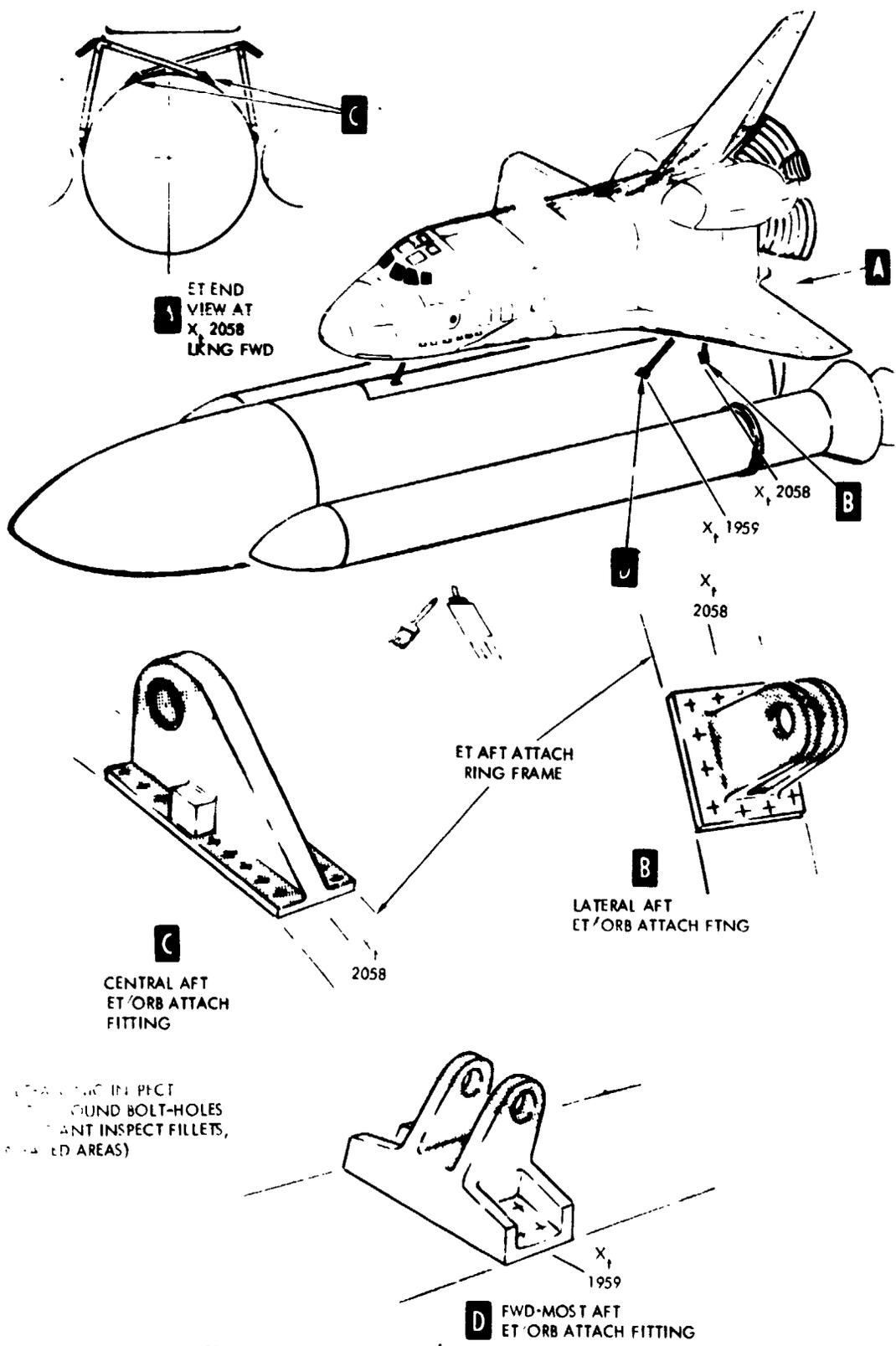


Figure 7-3. Aft ET/Orbiter Attach Fittings

PROCEDURE NO: 7-805, FIGURE 7-4
MAJOR ASSEMBLY: EXTERNAL TANK, ZONE 8
SUBASSEMBLY: AFT ET/ORB INTERFACE
DRAWING(S): VL72-000103A, VL72-000009,
VL78-000028

TYPE INSPECTION:

(X) PREFLIGHT

COMPONENT/AREA DESCRIPTION: AFT ET/ORB ATTACH TRUSSES. The six ET clevis attach fittings mate with titanium (5Al-2.5Sn) truss tubes that interconnect the ET and Orbiter. The trusses receive high tensile and compressive flight loads during lift-off and ascent. The trusses must be free of significant defects during this crucial period. Sustained static fit-up loads and wind gusts while on the launch pad may produce damage in the end attachments of the truss tubes. In the event of high pre-launch winds and/or excessive launch hold the trusses should be inspected prior to launch.

DEFECTS: Radial cracks in the clevis and attachment areas and the multi-truss attachment fittings at the Orbiter attachment area.

ACCESS: The truss inspection areas are accessible from outside the ET and Orbiter. A boom and work platform will be required for proper elevation on the launch pad.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3 B) for clevis attach bolt holes; fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) for the multi-truss attach fitting.
Backup: Eddy current bolt hole (Para. 1.5.4.3).

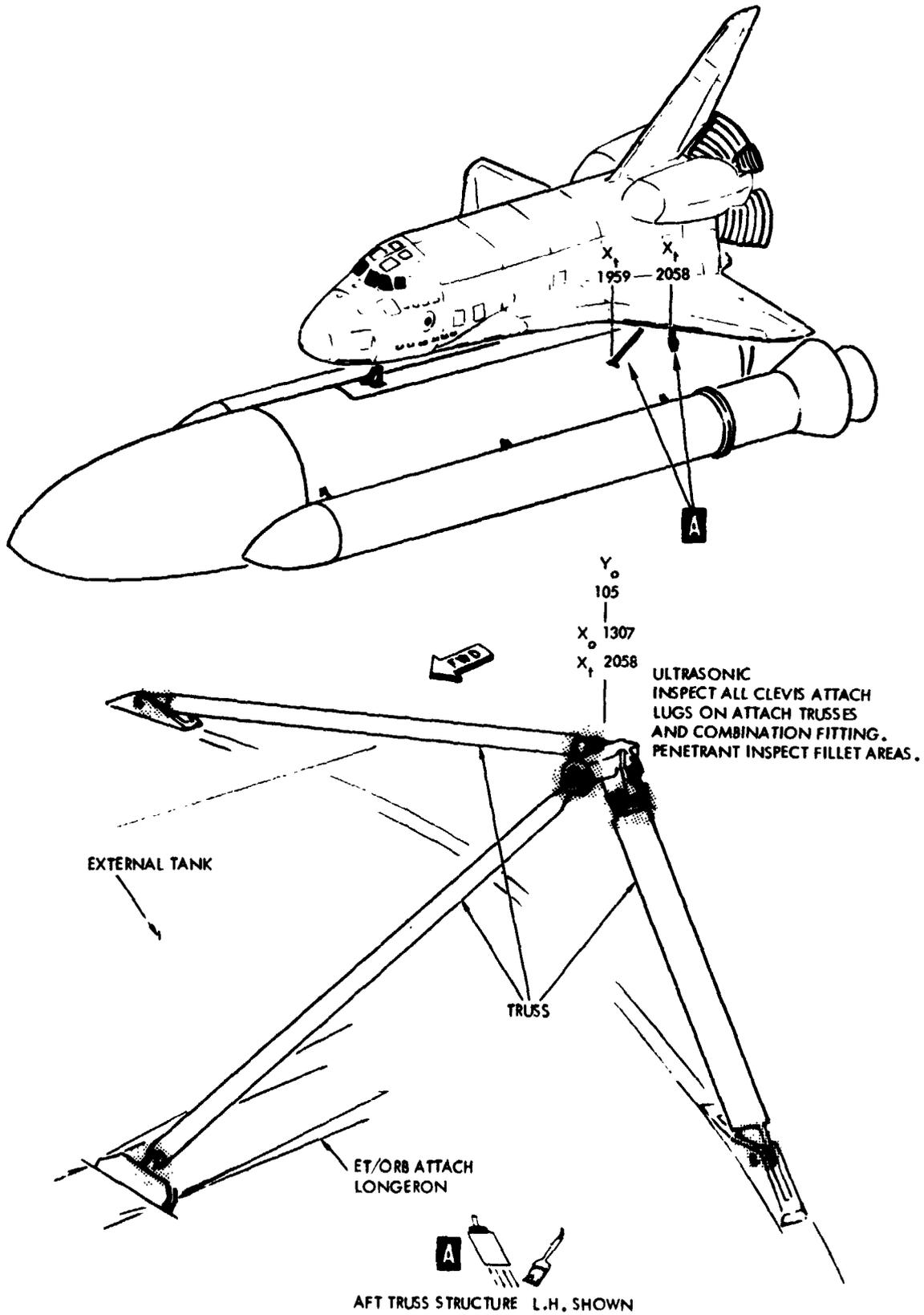


Figure 7-4. Aft ET/Orbiter Attach Trusses

PROCEDURE NO: 7-806, FIGURE 7-5
MAJOR ASSEMBLY: EXTERNAL TANK, ZONE 8
SUBASSEMBLY: AFT ATTACHMENT INTERFACE
DRAWING(S): VL72-000103A, VL78-000024A

TYPE INSPECTION:

(X) PREFLIGHT

COMPONENT/AREA DESCRIPTION: ET/SRB AFT ATTACH FITTINGS. Two attach fittings are located on each side of the ET at X₁ 2052 along the intervehicular attachment frame. These fittings mate with support trusses that connect the SRB and ET on each side of the ET. High tensile loads between the two vehicles of 364K are reacted through each of two such trusses and the fittings. The fitting is made of titanium (5Al-2.5Sn). Inspections should be made on the fittings after mating prior to launch if the vehicle remains mated for a lengthy time, particularly if subjected to high wind gusts during this period.

DEFECTS: While subjected to high static and wind loads on the launch pad, cracks may occur at the bolt holes or in the fillet where the lug blends into the base.

ACCESS: Access is readily attained by the use of platforms or booms while the Shuttle is in the vertical launch attitude.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3 B) and fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9).
Backup: Eddy current bolt hole (Para. 1.5.4.3) or fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) for attach hole.

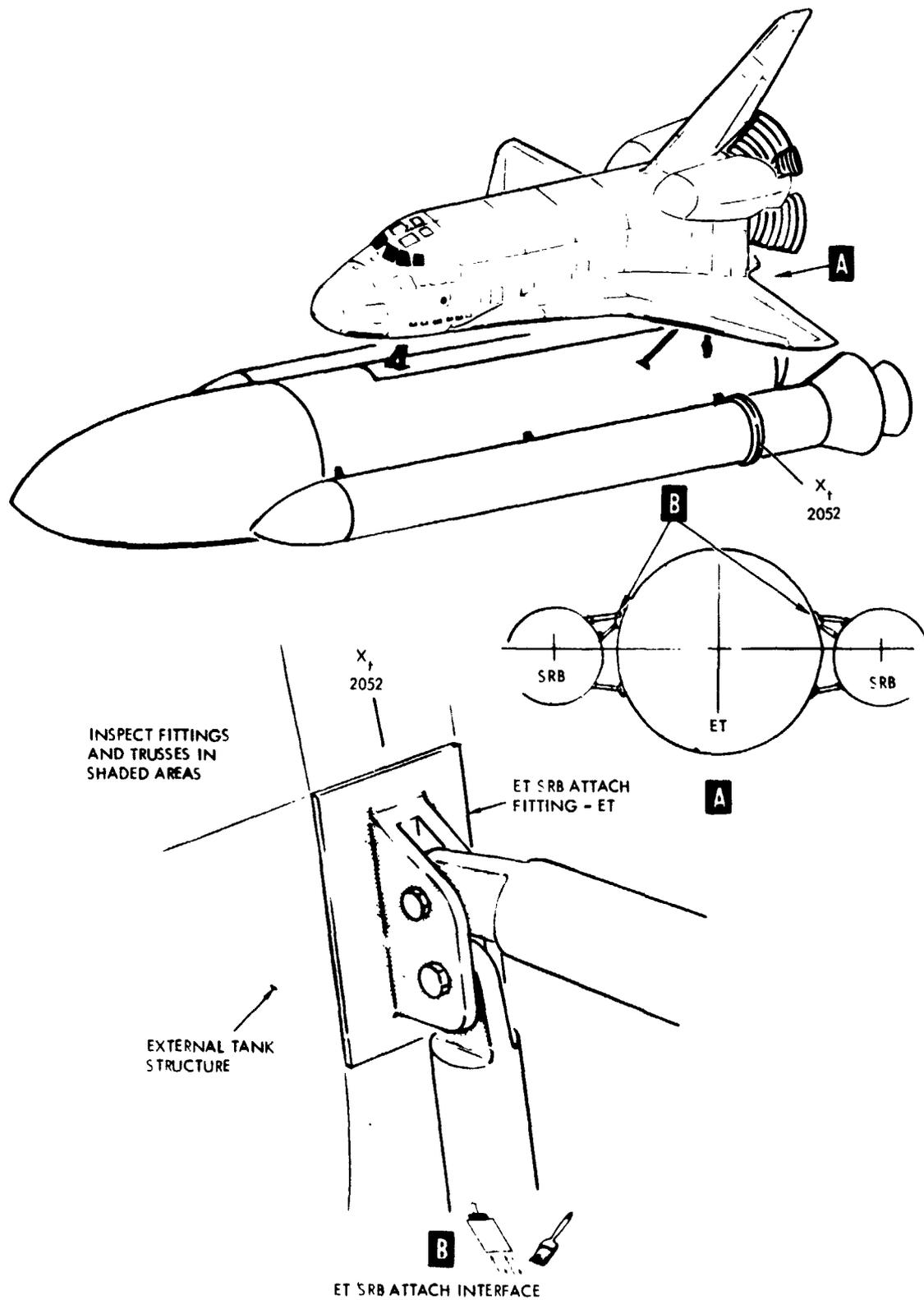


Figure 7-5. ET/SRB Aft Attach Fittings

SECTION 8. SOLID ROCKET BOOSTER STRUCTURE

This section contains the preflight and postflight NDE requirements for the solid rocket motor case and propellant, separation motors, TVC actuators, parachute recovery system structure, SRB/ET forward and aft attach structure, and nozzle assemblies.

SECTION 8
TABLE OF CONTENTS

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
8-901	SRB Recovery System Parachutes and Attachments	8-1
8-902	SRB Separation Motors Including Ignition Control	8-4
8-903	SRB Interfacing	8-8
8-904	SRB/ET Forward Attachment Interface	8-11
8-905	SRM Igniter	8-13
8-906	SRM Segment Membrane	8-15
8-907	SRM Segment Clevis Joint	8-18
8-908	SRM Assembly Hardware	8-20
8-909	SRM Nozzle and Igniter Attachment Boss	8-23
8-910	SRB Propellant Surfaces	8-26
8-911	SRB Propellant to Insulation Bond	8-27
8-912	SRB Insulation to Case Bond	8-28
8-913	SRB Insulation to Release Flap Bond	8-29
8-914	ET/SRB Aft Attach Fittings and Trusses	8-32
8-915	SRB Thrust Vector Control (TVC) Structure and Assembly	8-34
8-916	SRB Flexible Seal (TVC)	8-37
8-917	SRB Nozzle Shell	8-39
8-918	SRB Nozzle Ablatives	8-42
8-919	SRM Joint Seals	8-44

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SECTION 8
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
8-1	Recovery System Parachutes and Attachments	8-3
8-2	Separation Motors, Ignition Control	8-7
8-3	SRB Interfacing	8-10
8-4	ET/SRB Forward Attach Fitting	8-12
8-5	SRM Igniter	8-14
8-6	SRM Segment Membrane	8-17
8-7	SRM Segment Clevis Joint	8-22
8-8	Nozzle and Igniter Attachment Boss	8-25
8-9	Propellant Grain and Case Interfaces	8-30
8-10	ET/SRB Aft Attach Fittings and Trusses	8-33
8-11	Thrust Vector Control Structure and Assembly	8-36
8-12	Nozzle Flexible Seal	8-38
8-13	Nozzle Shell	8-41
8-14	Nozzle Ablatives	8-43
8-15	SRM Segment Joint Pressure Seals	8-46

PROCEDURE NO: 8-901, FIGURE 8-1
MAJOR ASSEMBLY: SRB FORWARD STRUCTURE, ZONE 9
SUBASSEMBLY: RECOVERY SYSTEM PARACHUTES
AND ATTACHMENTS

TYPE INSPECTION:
(X) POST RETRIEVAL

COMPONENT/AREA DESCRIPTION:^{*} The parachute recovery system incorporates three main chutes per SRB with a canopy diameter of 130 feet and approximate slack length of 300 feet that attach to the nose of the SRB and are deployed as a part of the recovery sequencing. Deployment devices include altitude sensors, pyrotechnic ejection systems (mortar) and nose cone frustum separation devices. Other recovery elements include a parachute flotation pack and various radar sonar and visual beacons to aid in location of SRM while yet airborne and after water impact. The parachute attachment structure should be inspected for damage after recovery.

^{*} System design is incomplete. This description is based upon best available information.

DEFECTS: Damage, corrosion and possibly cracks in the parachute attachment structure. The parachute system will be retrieved along with the SRB after water impact. If parachute separation is successfully accomplished, it is probable that the chutes will be retrieved without significant damage. If, however, entanglement between chutes or with the SRB occurs, the probability of damage to the shrouds or ribbon canopy components is high. Drying and the resultant formation of salt crystals creates a high damage potential through crystal abrasion.

ACCESS: The parachute attach structure is accessible inside the SRB forward cone. The parachutes will be retrieved by winching aboard a recovery vessel and reeling onto drums established for the purpose. Access is thus limited to a cursory inspection while in the water and while in the process of reeling the chute, or a more detailed inspection later after the chute is removed from the drum. Current planning indicates the possibility of retaining the chute on the drum, encapsulation to

PROCEDURE NO: 8-901, FIGURE 8-1 (continued)

maintain high moisture content conditions and direct shipment from KSC to the point of parachute refurbishment. The alternate approach would provide removal from the drum at KSC dockside facilities and immediate washing, drying, and detailed inspection for which access would be a function of the operations encompassed therein.

NDT TECHNIQUES: Inspect the parachute attach structure with fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9). In the event that the parachutes are encapsulated and shipped directly to the refurbishment contractor, no further KSC inspection is required. If KSC inspection is required (assuming facilitization for the purpose) primary inspection means will be detailed visual inspection aided by selective strength testing of parachute ribbon and lines. Commercially available equipment for fabric testing would be used for this purpose.

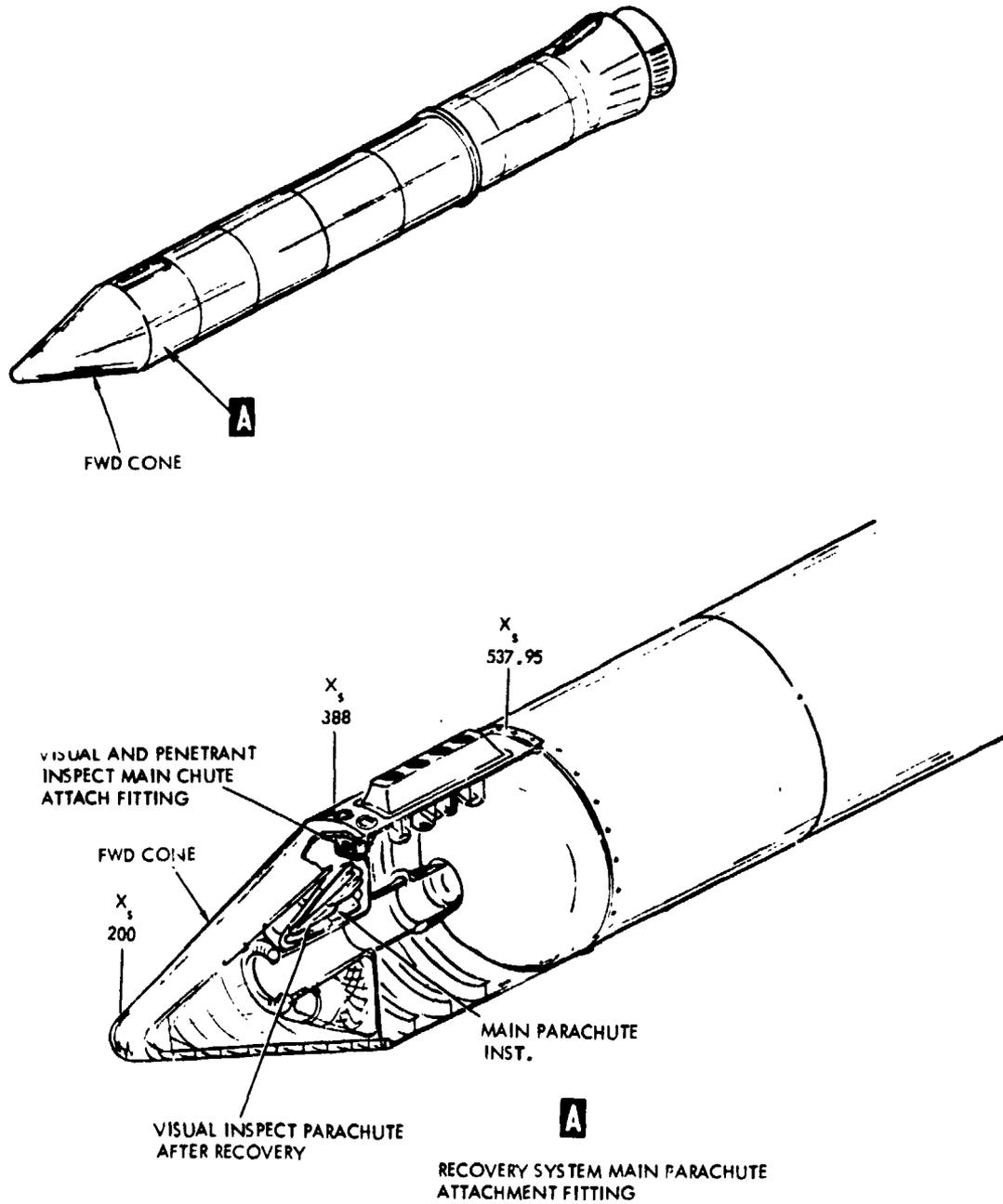


Figure 8-1. Recovery System Parachutes and Attachments

<u>PROCEDURE NO:</u>	8-902, FIGURE 8-2	<u>TYPE INSPECTION:</u>
<u>MAJOR ASSEMBLY:</u>	SRB FWD AND AFT STRUCTURES, ZONE 9	(X) PREFLIGHT (X) POST RETRIEVAL
<u>SUBASSEMBLY:</u>	SEPARATION MOTORS, INCLUDING IGNITION CONTROL	(X) NON CONFORMANCE

COMPONENT/AREA DESCRIPTION: A series of small rocket motors in the forward and aft SRB structures will be used to supply separation thrusting following SRM burnout. The number of units per SRB has not been determined, but is expected to be in the range of 8 to 10 each end of each SRB. Ignition control may be expected to be similar to that of the SRM, using a mechanical barrier system and a separate electrical power supply. The system may utilize a single safe/arm with pyrotechnic ignition trains (detonating fuse or similar) leading to the individual rocket motors. The SRB forward and aft structures will contain mounting provisions for the separation rocket motors which will be emplaced and secured individually during buildup of the SRB structures.

DEFECTS: The rocket motors may be expected to arrive in individual shipping containers, thus are probably not subject to major damage that is visually evident upon opening of the containers. Transit damage can occur, however, from very high G forces encountered in mishandling and would be noted only in evaluation of the propellant grain for cracks and separations. Similar damage could occur in the rocket motor igniter through compacting, crumbling, or separation of pyrotechnic materials to the point where ignition time delays could be encountered in firing. Damage to the safe/arm devices would be as described for the SRM. The motor mounts may experience damage due to thrust transients and/or exposure to sea water after sea-impact.

ACCESS: The separation rockets will likely be shipped as three components; the motor, the nozzle, and the igniter. These units may be readily visually inspected as received. The separation motor propellant grain, depending upon design, may be accessible for boroscope inspection. Once installed in the SRB structures, accessibility is probably limited to external view of the nozzle exit plane. Similar

PROCEDURE NO. 8-902, FIGURE 8-2 (continued)

accessibility is available on other components. Post-retrieval disassembly will be necessary to inspect the motor mounts.

NDT TECHNIQUES: Until the effect of potential shipping damage is clearly established, the rocket motor propellant grains should be thoroughly inspected upon receipt. Radiography (Para. 1.5.6.2) should be utilized for early inspections to establish confidence in motor transportability. After development, radiography can be used for nonconformance inspection only. For all motors, the grain port should be visually inspected with a boroscope (Para. 1.5.1.3) to ascertain a void-free, crack-free condition. The igniter should be visually inspected, or subjected to radiography (Para. 1.5.6.2) on the same schedule as the rocket motor if visual inspection cannot ascertain internal defects. Visual inspection would suffice for the nozzle.

An alternate technique to propellant radiography might encompass a transportation and shock test program of sufficient magnitude to assure structural integrity of the rocket motors through a wide range of conditions coupled with inclusion of recording devices in the shipping containers that will establish levels of shock loading during transit.

Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) or eddy current (Para. 1.5.4.4) inspection can be applied to the motor mounts after they have been thoroughly cleaned of salt crystals and corrosion products if present.

NON-CONFORMANCE: In the event that visual and boroscope inspection reveal anomalous propellant grain conditions, radiographic inspection should be considered mandatory for determination of degree of nonconformance. The technique used should be identical to those established by the motor manufacturer to allow direct comparison to the manufacturer's films, if required. Existing radiographic equipment at the KSC area should support this need.

PROCEDURE NO. 8-902, FIGURE 8-2 (continued)

Nonconforming conditions established during inspection are probably nonrepairable and would result in a Return-to-Vendor status.

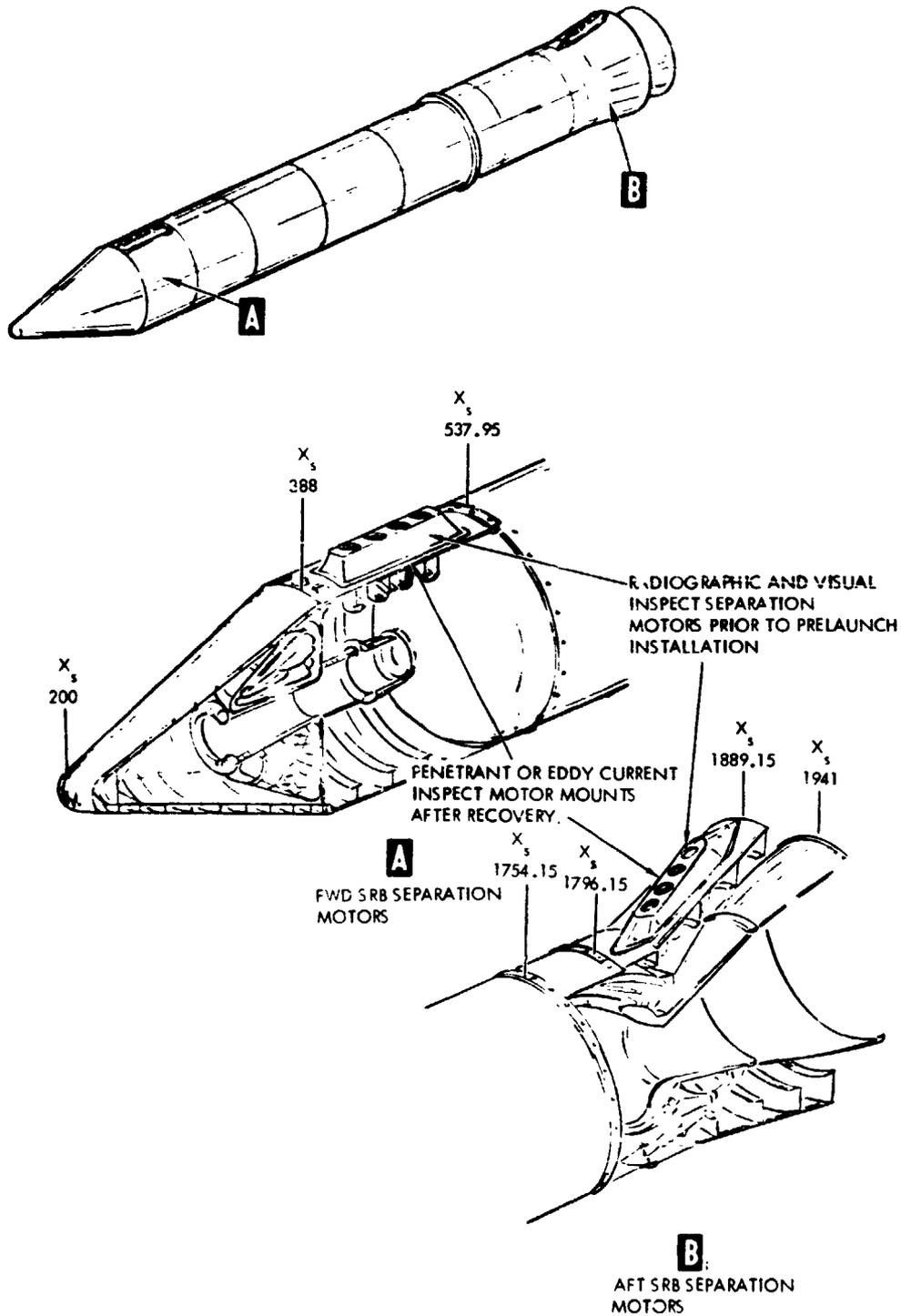


Figure 8-2. Separation Motors, Ignition Control

PROCEDURE NO: 8-903, FIGURE 8-3

MAJOR ASSEMBLY: SRB/ET, ZONE 9

SUBASSEMBLY: SRB INTERFACING

TYPE INSPECTION:

(X) PREFLIGHT

(X) POST RETRIEVAL

(X) NON CONFORMANCE

COMPONENT/AREA DESCRIPTION: The ET is mated to two SRBs following SRB assembly and checkout. Interfaces include both interstage structures that carry static and dynamic loads and electrical/electronic umbilical connections to the ET for control and power between assemblies. The mechanical structure has provision for prelaunch alignment between the SRB and ET which in turn sets the prelaunch alignment of the entire Shuttle vehicle on the pad. Additional mechanisms provide release of the SRB from the ET for the separation phase of the launch. These mechanisms may incorporate pyrotechnic components and associated safety devices. Electrical interfaces are not completed at this stage since full circuitry is dependent upon mating of ET interfaces to power and avionics contained in the orbiter vehicle.

DEFECTS: Structural member defects include damage to the primary structure or jamming of alignment mechanisms through in-transit damage, mishandling or retrieval impact or handling.

Electrical/electronic defects would be typical of umbilical cables and connections, including mismating, loss of continuity, bent connector pins, improper grounds and similar items. Since alignment of the total vehicle is a part of the interface, control of this attribute is paramount in the buildup of the SRM/SRB and subsequent mating of the ET.

ACCESS: Interstage structures are accessible as components and (assumed) accessible from work platforms during launch buildup in the VAB. Further accessibility after move to the launch pad is probably difficult but not likely to be required. Electrical connections should be readily accessible during launch buildup.

PROCEDURE NO. 8-903, FIGURE 8-3 (continued)

NDT TECHNIQUES: Prelaunch - evidence of structural damage determined by visual inspection or observation of handling impact should be evaluated by standard metal parts techniques such as penetrant (Para. 1.5.2.1) or flawed areas or measurement of bow or other distortion with standard mechanical instruments or optical alignment instruments.

Specific alignment of the SRM/SRB and ET mating and adjustments should be accomplished with special optical test equipment using a sequence substantially as follows:

- a. During SRM/SRB buildup, establish SRM thrust centerline in relation to SRB structural attach points and to the mobile launch platform on two SRBs.
- b. Attach interstage structures to the two SRBs, align for mating to the ET.
- c. Mate ET and align the assembly of two SRBs and one ET.

POST RETRIEVAL: Retrieved structural members should be visually examined for gross damage and returned to the supplier for refurbishment. If refurbishment is contemplated as a part of KSC operations, the items should be subjected to a remanufacturing cycle including refurbishment of protective coatings, gaging or measurement of critical dimensions, evaluation of machined surfaces and similar operations to assure acceptance to original design criteria.

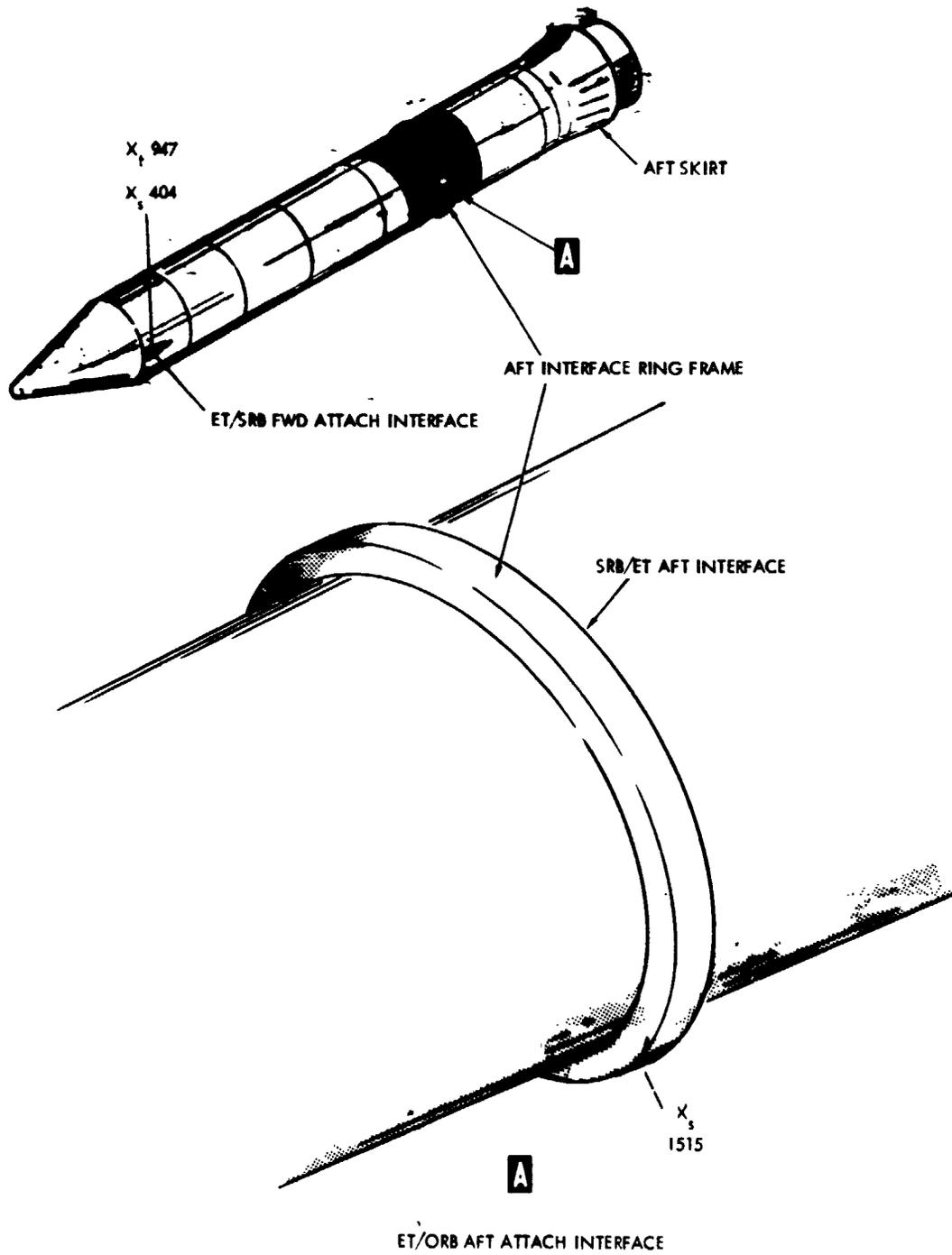


Figure 8-3. SRB Interfacing

PROCEDURE NO: 8-904, FIGURE 8-4

TYPE INSPECTION:

MAJOR ASSEMBLY: SRB

SUBASSEMBLY: SRB/ET FWD ATTACHMENT
INTERFACE

(X) POSTFLIGHT
(X) PREFLIGHT

DRAWING(S): VL72-000103A

COMPONENT/AREA DESCRIPTION: ET/SRB FWD ATTACHMENT FITTING. This fitting, one on each SRB vehicle, mates with a similar fitting on the ET to connect the two SRB's and ET together during pre-launch, launch and (Phase I) ascent. The safe-life fitting is a D6AC (or 18% N; Maraging) steel machined forging. One fitting is located on the fwd right side of the left-hand SRB at X_s 404, Y_s -71, and Z_f 400 (the right-hand SRB is similar with Y_s +71). The fittings react intervehicular G-loads, vibro-acoustics, wind buffeting, aerodynamic and ascent maneuver loads. The design mode is for high tensile loads during maximum acceleration. Post-flight inspection should reveal damage from these causes. In addition, the fittings should be inspected prior to launch if the Shuttle has remained on the launch pad for an excessive time during adverse wind and salt humidity conditions.

DEFECTS: Cracks may occur in or near the attachment surfaces due to the above conditions.

ACCESS: Access is readily attained for inspection of the recovered SRB in the post retrieval maintenance shop. Access for preflight inspection is attained by the use of booms while the Shuttle is in the vertical launch attitude.

NDT TECHNIQUES: Primary: Visual and penetrant (Para. 1.5.2.1, Fig. 1-9).
Backup: Eddy current (Para. 1.5.4.4).

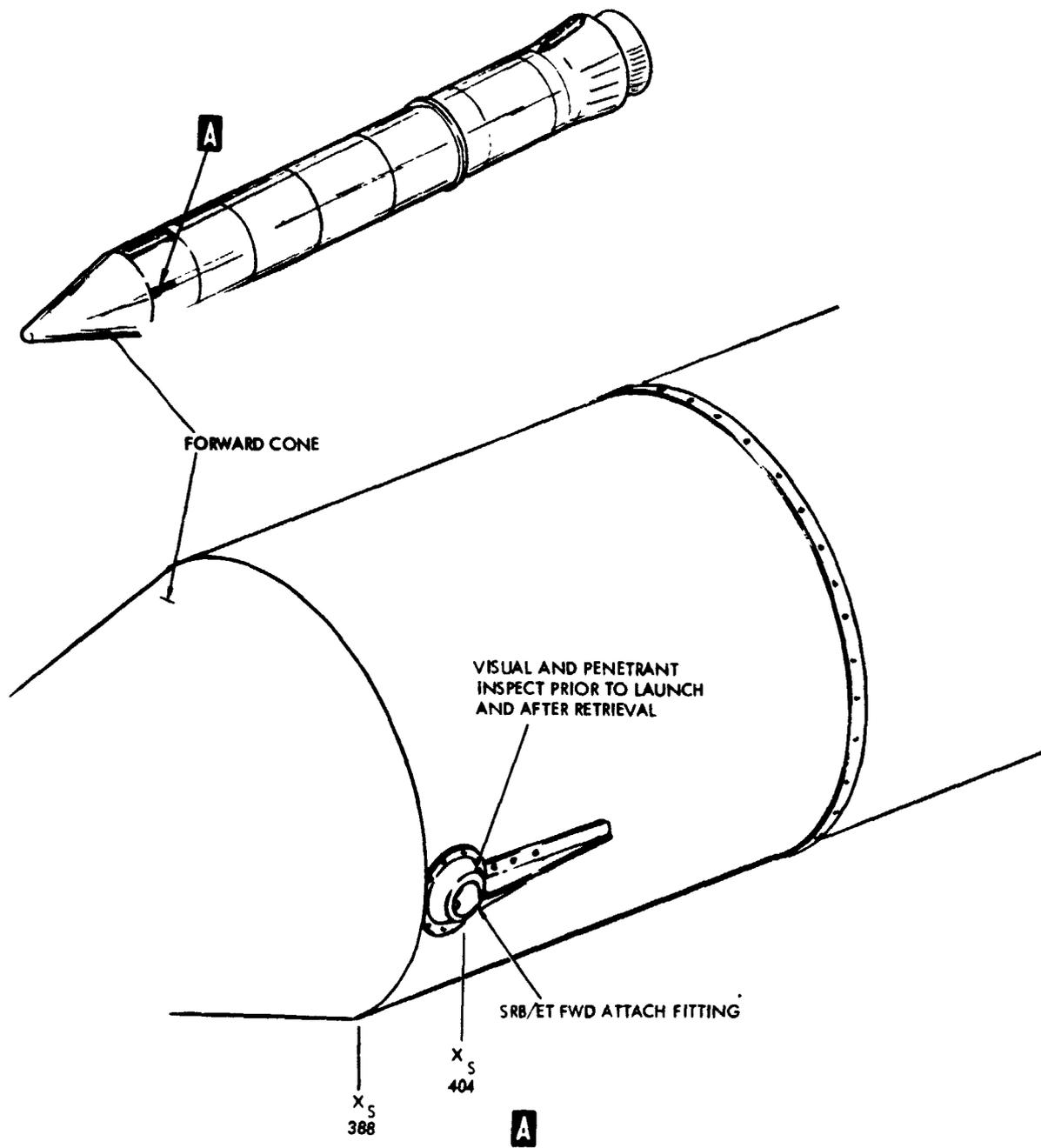


Figure 8-4. ET/SRB Forward Attach Fitting

PROCEDURE NO: 8-905, FIGURE 8-5

MAJOR ASSEMBLY: SRB, SRM IGNITION SYSTEM
ZONE 9

SUBASSEMBLY: IGNITER

TYPE INSPECTION:

(X) PREFLIGHT

(X) POST RETRIEVAL

COMPONENT/AREA DESCRIPTION: The pyrogen igniter is a small rocket motor and consists of a motor case, a propellant grain and an ignition system consisting of a first fire charge and a BKNO_3 pellet basket.

DEFECTS: The igniter motor is susceptible to the same defects as described for the SRM motor.

ACCESS: If the igniter is delivered assembled, only the outside of the motor case is accessible. Depending upon the type of joint and seal design, it might not be practical to disassemble the motor for inspection at the launch site.

NDT TECHNIQUES: If the igniter components are assembled at the launch site and are available for visual inspection, no additional NDT is required. If the igniter is received assembled and cannot be visually inspected, a radiographic inspection (Para. 1.5.6.2) of the assembly is recommended to inspect for presence of seals, grain integrity and condition of BKNO_3 .

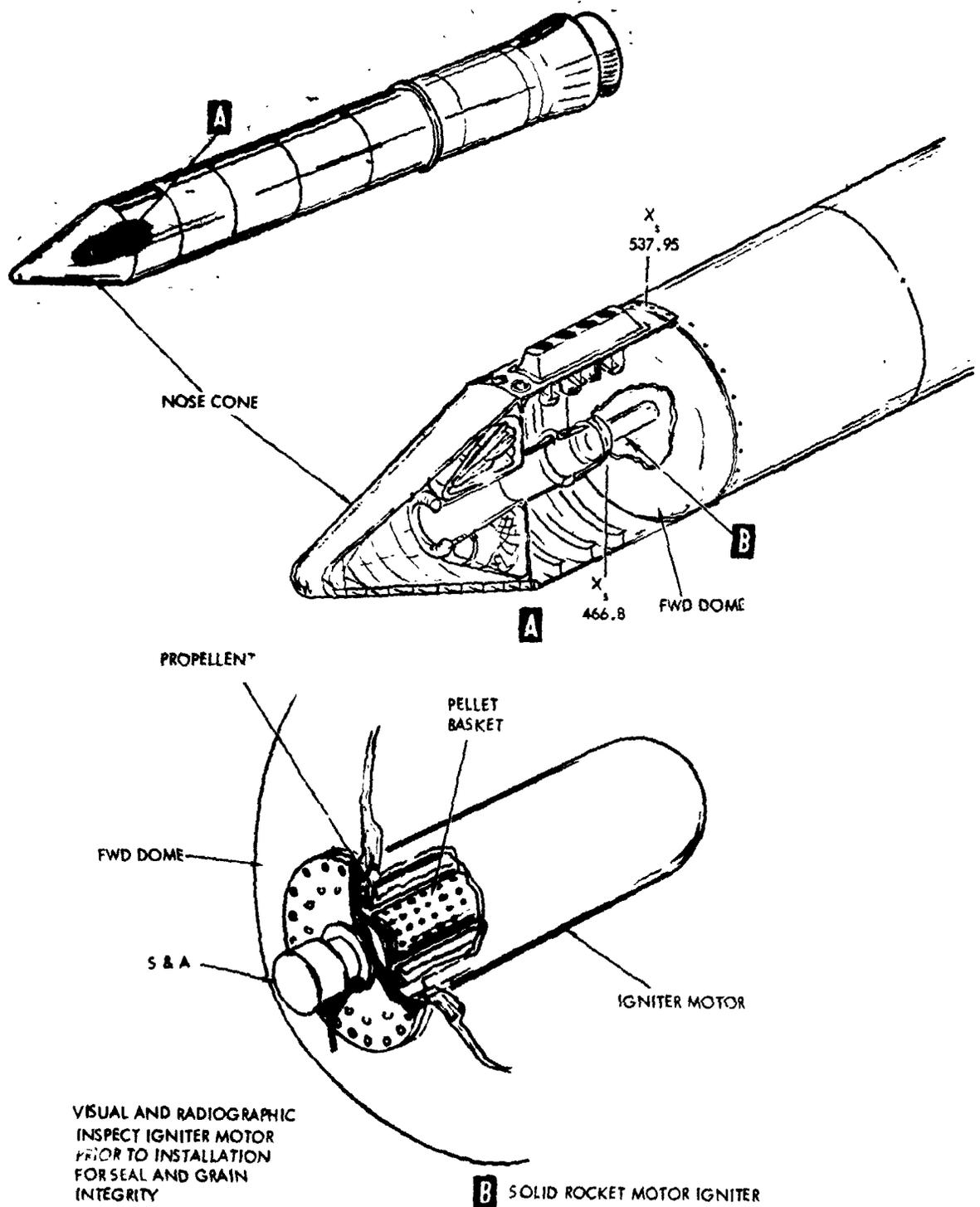


Figure 8-5. SRM Igniter

<u>PROCEDURE NO:</u>	8-906, FIGURE 8-6	<u>TYPE INSPECTION:</u>
<u>MAJOR ASSEMBLY:</u>	SRB, SRM CASE, ZONE 9	(X) PREFLIGHT
<u>SUBASSEMBLY:</u>	SRM SEGMENT MEMBRANE	(X) POSTFLIGHT
		(X) NONCONFORMANCE

COMPONENT/AREA DESCRIPTION: The SRM case is segmented and consists of center cylinder segments and end dome (closure) segments that are joined by clevis joints, all of the segments are fabricated from D6aC steel. The cylinder segments and end dome segments contain thin membrane sections between the end joints. These thin membrane sections are designed for ultimate pressure loading and have a safety factor equal to the minimum requirement of 1.4.

DEFECTS: Transportation and handling of the heavy case cylinder and dome segments subject the thin membrane areas to possible damage such as dents, scratches, and corrosion pitting. Similar defects can occur during water recovery and retrieval. Since these membrane areas are designed near optimum, defects of this nature can cause failure.

Defects of these areas will be detected by standard prelaunch and post-retrieval visual inspection of the case segments. If defects are detected, special nonconformance inspection as described below will be required.

ACCESS: The segment membrane is accessible from the outside of the case except under the raceway brackets. The raceway brackets will provide protection from these types of defects however. The outside of the case will be painted, so local removal of the paint will, in most cases, be required.

NDT TECHNIQUES: If the standard prelaunch or post-retrieval visual inspection reveals defects, the following non-conformance inspection will be required.

1. Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) inspect damaged area to determine extent of damage, after removal of protective

PROCEDURE NO. 8-906 , FIGURE 8-6 (continued)

coating from the area adjacent to the damage .

2. Use an ultrasonic thickness tester (Para. 1.5.5.4) to determine membrane thickness adjacent to the damaged area .
3. After blending or repair of the damaged area, check membrane thickness at base of flaw location by ultrasonic thickness tester (Para. 1.5.5.4).
4. Penetrant inspect (Para. 1.5.2.1, Fig. 1-9) defect area to assure complete flaw removal .
5. Recoat area and test thickness of protective coating applied with magnetic or eddy current thickness gage . Type of NDI coating thickness gage will be dependent on type of protective coating used on case exterior .

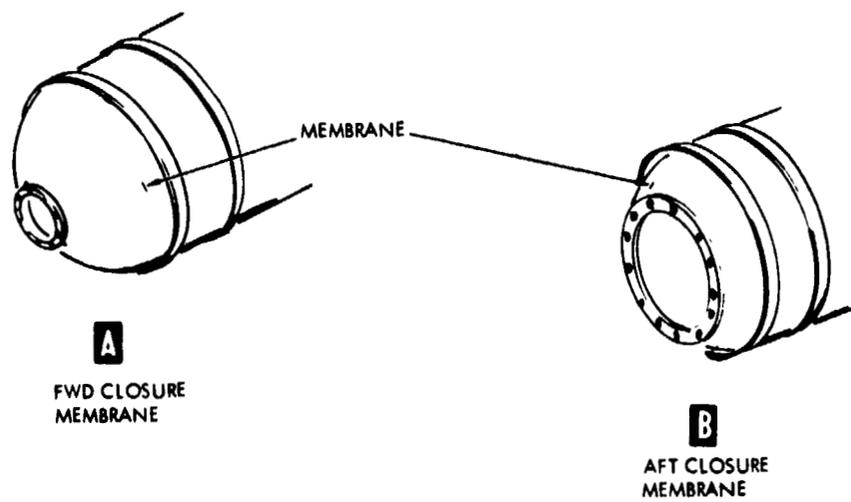
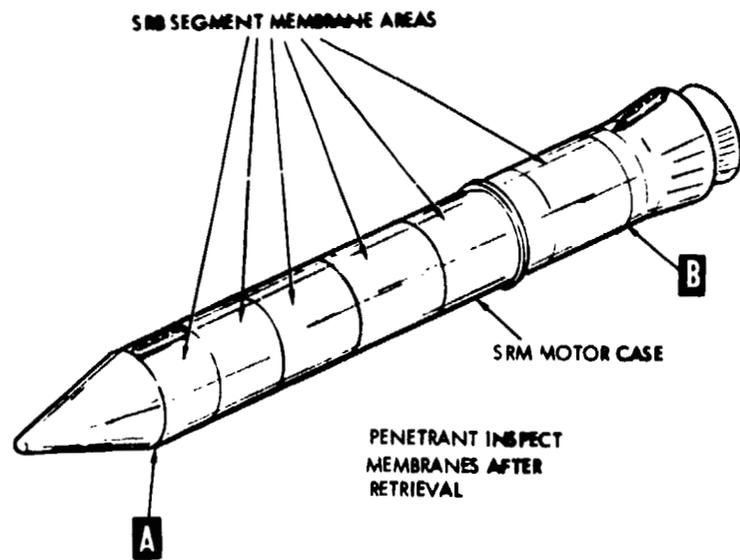


Figure 8-6. SRM Segment Membrane

PROCEDURE NO: 8-907, FIGURE 2-7

MAJOR ASSEMBLY: SRB, SRM CASE, ZONE 9

SUBASSEMBLY: SRM SEGMENT CLEVIS JOINT

TYPE INSPECTION:

(X) PREFLIGHT

(X) POST RETRIEVAL

(X) NON CONFORMANCE

COMPONENT/AREA DESCRIPTION: The case segments are joined by a clevis joint with shear pins. The pins and pin holes in the case require a close tolerance fit to assure proper sealing and load distribution through the joint. The O-ring sealing surfaces require a fine surface finish to assure proper sealing and cannot be painted to prevent surface corrosion and pitting.

The clevis joint pin holes will be used in transportation and handling for structural tie downs and segment lifting.

DEFECTS: Transportation and handling of the loaded segments can cause scratches or local yielding of the pin holes and scratches in the O-ring sealing surfaces. Since the clevis area cannot be permanently protected from corrosion, pitting of the unpainted surfaces may occur. These defects could also occur during water recovery and retrieval of the case.

Inspection of the clevis joints during standard prelaunch or post retrieval inspection will reveal the presence of any of the defects, which will then require nonconformance inspection.

ACCESS: The clevis joint is completely accessible before or after case assembly.

NDT TECHNIQUES: During prelaunch and post-retrieval inspection, the clevis joint should be 100 percent visually inspected. The pin holes that are used during transportation or handling should be dimensionally checked using an ID air gage. If these inspections reveal any defects, the following non-conformance inspection should be conducted.

1. Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9 or Fig. 1-10)
inspect the damaged area.

PROCEDURE NO. 8-907, FIGURE 8-7 (continued)

- 2. (a) Check membrane thickness adjacent to the damaged area using ultrasonic thickness tester (Para. 1.5.5.4) or in-accessible areas of the male joint use standard measuring tools (Micrometer).**

(b) For non-conforming pin holes, the inside diameter should be inspected using eddy current bolt hole inspection (Para. 1.5.4.3).
- 3. After blending or repair, check membrane thickness of defect location by method used in 2.**
- 4. Penetrant inspect (Para. 1.5.2.1, Fig. 1-9) area to assure flaw removal.**

PROCEDURE NO: 8-908, FIGURE 8-7
MAJOR ASSEMBLY: SRB, SRM CASE, ZONE 9
SUBASSEMBLY: ASSEMBLY HARDWARE

TYPE INSPECTION:
(X) PREFLIGHT
(X) POST RETRIEVAL
(X) NON CONFORMANCE

COMPONENT/AREA DESCRIPTION: Each clevis joint of the SRM case is assembled with steel pins. The pins are retained in place with a pin retainer, which also serves to keep water out of the clevis joint. Pressure seals are provided by O-ring(s). Shear loads on the pins may cause damage to them, particularly if corrosion is present. If the pins are to be reused they should be fully inspected for damage.

DEFECTS: The pins, pin retainer, and O-rings should be shipped in protective boxes and should not undergo damage during handling or transportation. Potential defects would be corrosion pits, scratches, or gouges for the metal parts and scratches for the O-rings. Circumferential cracks may occur in the pin, emanating from a small undetected corrosion pit or foreign inclusion.

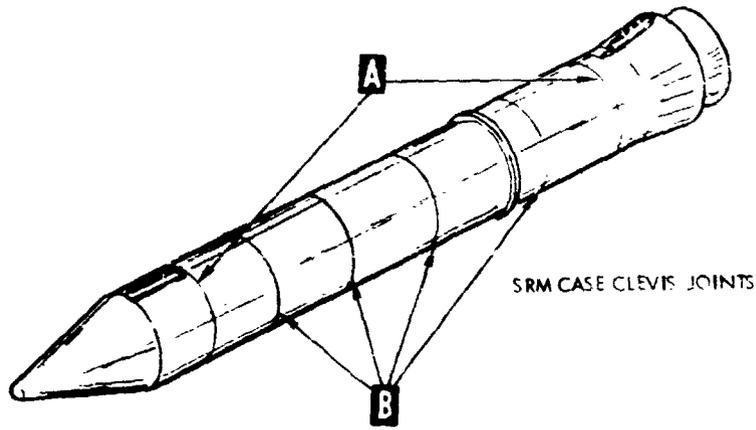
ACCESS: The pins, pin retainer and O-rings are 100% accessible.

NDT TECHNIQUES: The pins, pin retainer and O-rings should undergo a 100 percent visual inspection during the standard prelaunch inspection. If the pins or O-rings are damaged, they should be rejected. Damage to the pin retainer would warrant a non-conformance inspection as described below. Magnetic particle inspect the pins for cracks (Para. 1.5.3.2 long.).

1. Fluorescent penetrant inspect (Para. 1.5.2.1, Fig. 1-9) damaged area to determine extent of damage, after removal of protective coating from area adjacent to the damage.
2. Use an ultrasonic thickness tester (Para. 1.5.5.4) to determine membrane thickness adjacent to the damaged area.
3. After blending or repair of the damaged area, check membrane thickness at base of flaw location by ultrasonic thickness tester.

PROCEDURE NO. 8-908, FIGURE 8-7 (continued)

- 4. Penetrant inspect (Para. 1.5.2.1, Fig. 1-9) defect area to assure complete flaw removal.**
- 5. Recoat area and test thickness of protective coating applied with magnetic or eddy current thickness gauge. Type of NDI coating thickness gage will be dependent on type of protective coating used on case exterior.**



SRM CASE CLEVIS JOINTS

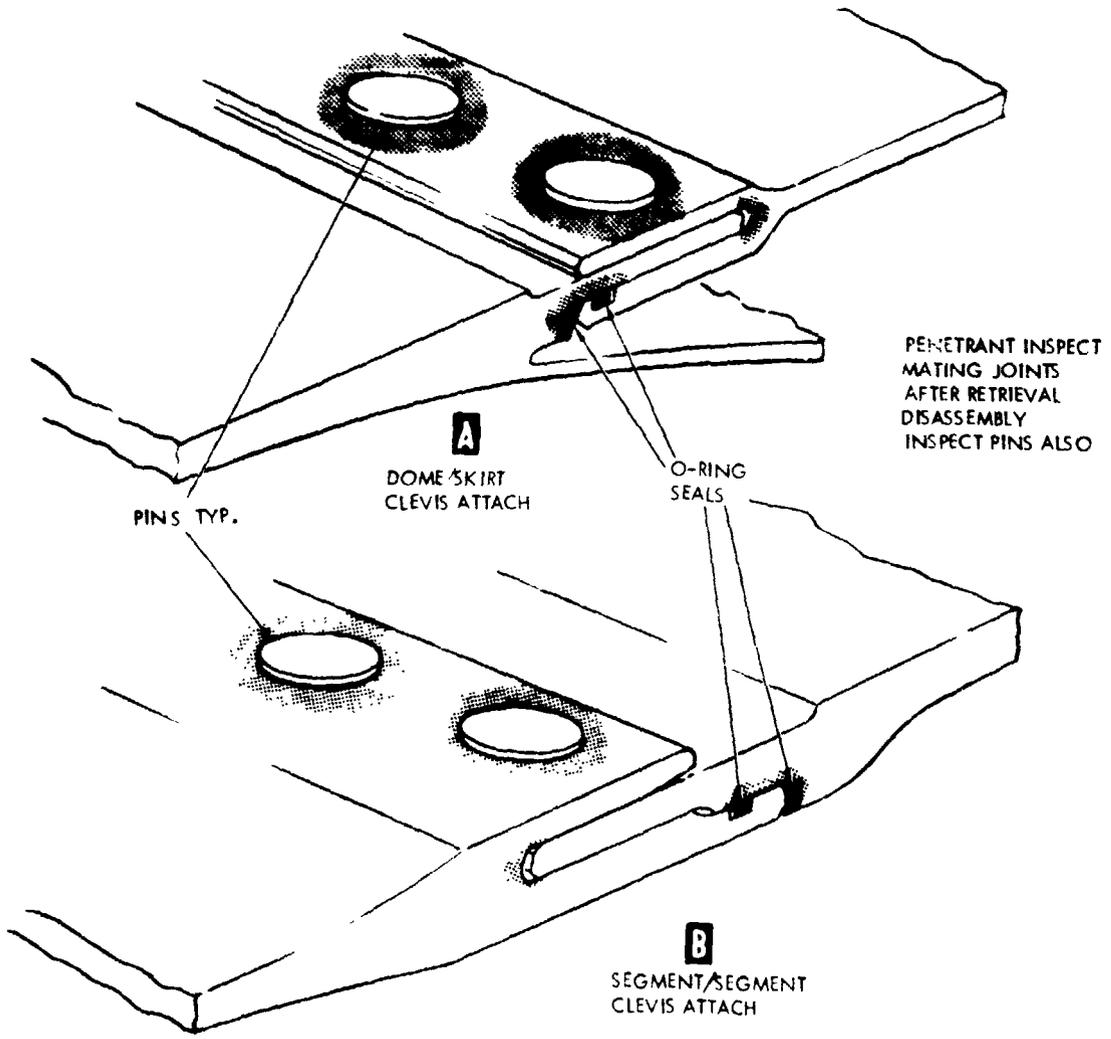


Figure 8-7. SRM Segment Clevis Joint

<u>PROCEDURE NO:</u>	8-909, FIGURE 8-8	<u>TYPE INSPECTION:</u>
<u>MAJOR ASSEMBLY:</u>	SRM CASE, ZONE 9	(X) PREFLIGHT
<u>SUBASSEMBLY:</u>	NOZZLE AND IGNITER ATTACHMENT BOSSES	(X) POST RETRIEVAL (X) NON CONFORMANCE

COMPONENT/AREA DESCRIPTION: The nozzle and igniter are attached to the case by bolting. A boss or built-up section is provided at these locations to allow thread holes in the case.

O-ring sealing surfaces are also provided which are protected from corrosion by oil or grease coatings. Shipping covers will be bolted to these joints during transportation.

DEFECTS: The installation or removal of the shipping covers could cause damage to the threaded bolt holes in the case attachment bosses. In addition, corrosion of the threads and/or O-ring sealing surface is possible. Similar defects can occur during water recovery and retrieval.

Defects of these areas will be detected by the standard prelaunch visual inspection of the case segments. If defects are detected, special nonconformance inspection as described below will be required. A more extensive inspection for cracks at the attachment holes should be made during post retrieval operations.

ACCESS: The threads and sealing surfaces are accessible for inspection.

NDT TECHNIQUES: If the standard prelaunch visual inspection reveals defects, the following non-conformance inspection will be required. For post retrieval inspection use fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9).

1. Fluorescent penetrant inspect (Para. 1.5.2.1, Fig. 1-9) damaged area to determine extent of damage.
2. Use an ultrasonic thickness tester (Para. 1.5.5.4) to determine thickness adjacent to the damaged area.

PROCEDURE NO. 8-909, FIGURE 8-8 (continued)

3. After blending or repair of the damaged area, check thickness at base of flaw location by ultrasonic thickness tester.
4. Penetrant inspect defect area to assure complete flaw removal.

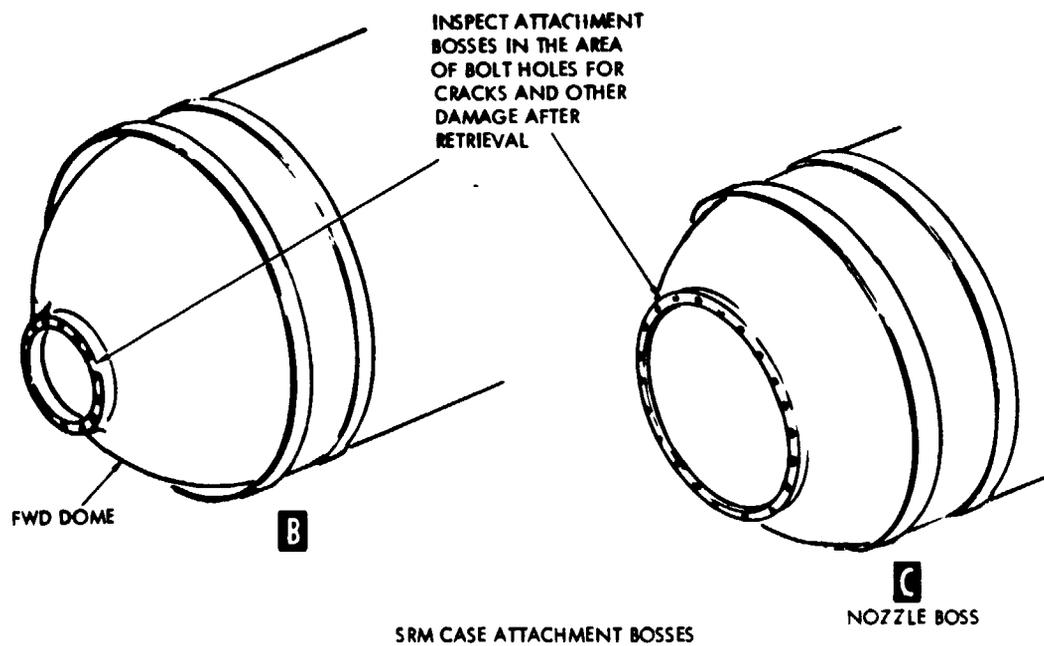
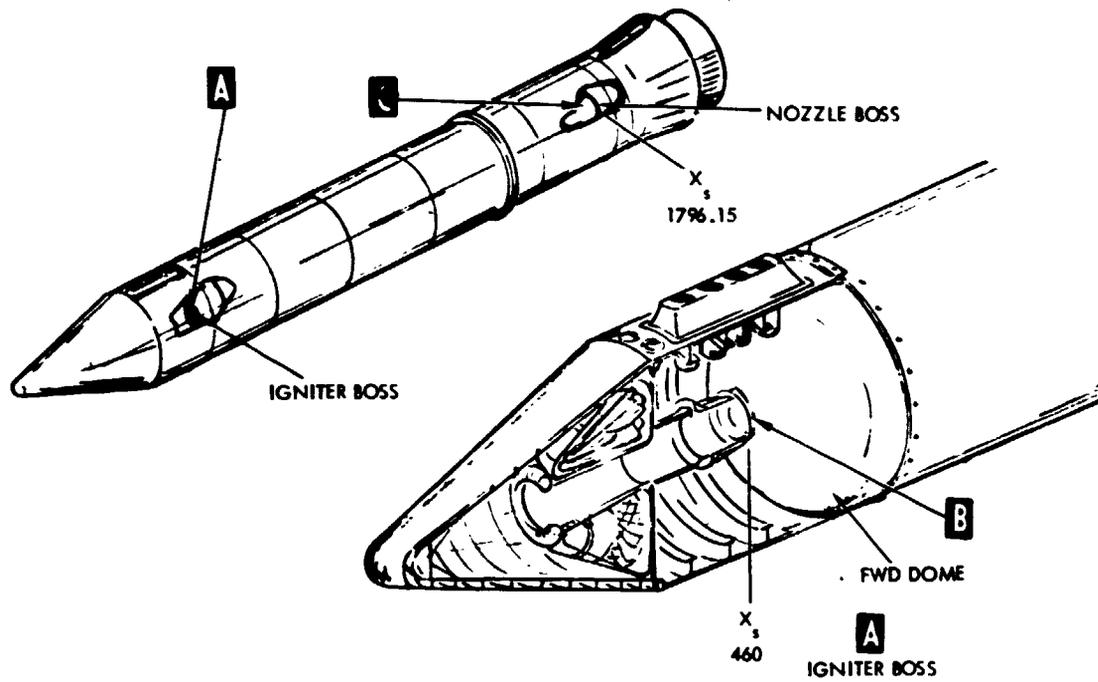


Figure 8-8. Nozzle and Igniter Attachment Boss

PROCEDURE NO: 8-910, FIGURE 8-9 TYPE INSPECTION:
MAJOR ASSEMBLY: SRB, PROPELLENT GRAIN (X) PREFLIGHT
ZONE 9
SUBASSEMBLY: PROPELLENT SURFACES

COMPONENT/AREA DESCRIPTION: The propellant grain of the SRM consists of cast segments, encased in the insulated motor case segments. The PBAN/aluminum/ammonium perchlorate grain is insulated from the 142 inch (3.61m) OD case segments by a bonded liner. The grains are characterized by either a 10-point star axial-cavity or truncated cone central perforation, depending upon location of the segment within the SRM assembly. One or both ends of specific segments may be covered with an inhibitor material that precludes direct access to the end grain surface.

DEFECTS: The bore of the propellant grain segment is susceptible to strain cracks induced by low temperature exposure or shipping and handling loads. No surface cracks are acceptable as they could cause catastrophic motor failure during ignition.

ACCESS: The propellant bore of each SRM segment is open at one or both ends and can be examined visually or with aids prior to pre-launch assembly.

NDT TECHNIQUES: The propellant grains should be visually inspected using optical aids (Para. 1.5.1.3). A recommended system is remote controlled TV cameras with zoom capability, and a TV monitor with standard photography accessories. The camera should have an illumination source free of infrared radiation so no heat is generated on the propellant surface. NOTE: A direct visual inspection by an individual in the mandrel area of the SRM is considered to be a high hazard condition. The remote controlled TV system is therefore required.

PROCEDURE NO: 8-911, FIGURE 8-9

TYPE INSPECTION:

MAJOR ASSEMBLY: SRB PROPELLANT GRAIN
ZONE 9

(X) PREFLIGHT

SUBASSEMBLY: PROPELLANT TO INSULATION
BOND

COMPONENT/AREA DESCRIPTION: The PBAN/aluminum/ammonium perchlorate propellant grain segments are 100% bonded to the lined and insulated case surface. The OD of the 0.5-inch thick D6aC steel motor casings is 142 inches (3.61m).

DEFECTS: Propellant to insulation bond failure may be induced by low temperature exposure or excessive handling or shipping loads. In addition, processing conditions during propellant casting, such as surface contamination of the insulation, can result in a weak bond which can later fail under normal loading conditions. The unbonds can occur at the propellant to liner or liner to insulation interfaces and can cause catastrophic motor failure due to excessive burn surface.

ACCESS: The bond surfaces are not accessible to visual inspection.

NDT TECHNIQUES: Recommended NDT technique is contact-pulse-echo ultrasonic inspection (Para. 1.5.5.6) performed on a grid pattern capable of detecting any critical unbond condition.

PROCEDURE NO: 8-912, FIGURE 8-9

MAJOR ASSEMBLY: SRB, PROPELLANT GRAIN,
ZONE 9

TYPE INSPECTION:

(X) PREFLIGHT

SUBASSEMBLY: INSULATION TO CASE BOND

COMPONENT/AREA DESCRIPTION: The internal insulation is 100 percent bonded to the motor case. The OD of the 0.5-inch thick, D6aC steel motor casings is 142 inches.

DEFECTS: The insulation to case bond is not critical unless gross unbonds of approximately 50 percent of the surface are present, or unless a gas path to the motor case exists.

ACCESS: The case to insulation bond is accessible visually at the ends of each insulated case segment.

NDT TECHNIQUES: For the DDT&E motors, the recommended NDT technique is contact-pulse-echo ultrasonic inspection (Para. 1.5.5.6) performed on a grid pattern capable of detecting any critical unbond condition. If no defects are noted on these motors, and no adverse effects due to motor transportation are detected, this inspection can be deleted and used only for motors which are exposed to unusual transportation environments.

Inspection should consist of 100% inspection at the transition area of the release flap to insulation bond. The balance of the bond should be inspected by a grid pattern capable of detecting unbonds greater than engineering requirements.

PROCEDURE NO: 8-913, FIGURE 8-9
MAJOR ASSEMBLY: SRB, PROPELLANT GRAIN
ZONE 9
SUBASSEMBLY: INSULATION TO RELEASE
FLAP BOND

TYPE INSPECTION:
(X) PREFLIGHT

COMPONENT/AREA DESCRIPTION: At the ends of the case segments, release flaps are bonded to the case insulation. The release flaps provide stress relief to the propellant grain to prevent stress cracks.

DEFECTS: Release flap unbond can be caused by low temperature exposure or handling and shipping loads. These loads produce the maximum stress at the flap to insulation bond termination.

ACCESS: The release flaps on each SRM segment are accessible to visual inspection prior to pre-launch assembly.

NDT TECHNIQUES: Recommended NDT technique is contact pulse-echo ultrasonics (Para. 1.5.5.6) on that portion of the aft or forward grain that is covered by a release flap or inhibitor. No pre-launch inspection is recommended of the cylindrical section of the release flap to insulation bond because this bond line is under a very low stress load. If no defects are noted on the DDT&E motors, this inspection can be deleted and used only for motors which are exposed to unusual transportation environments.

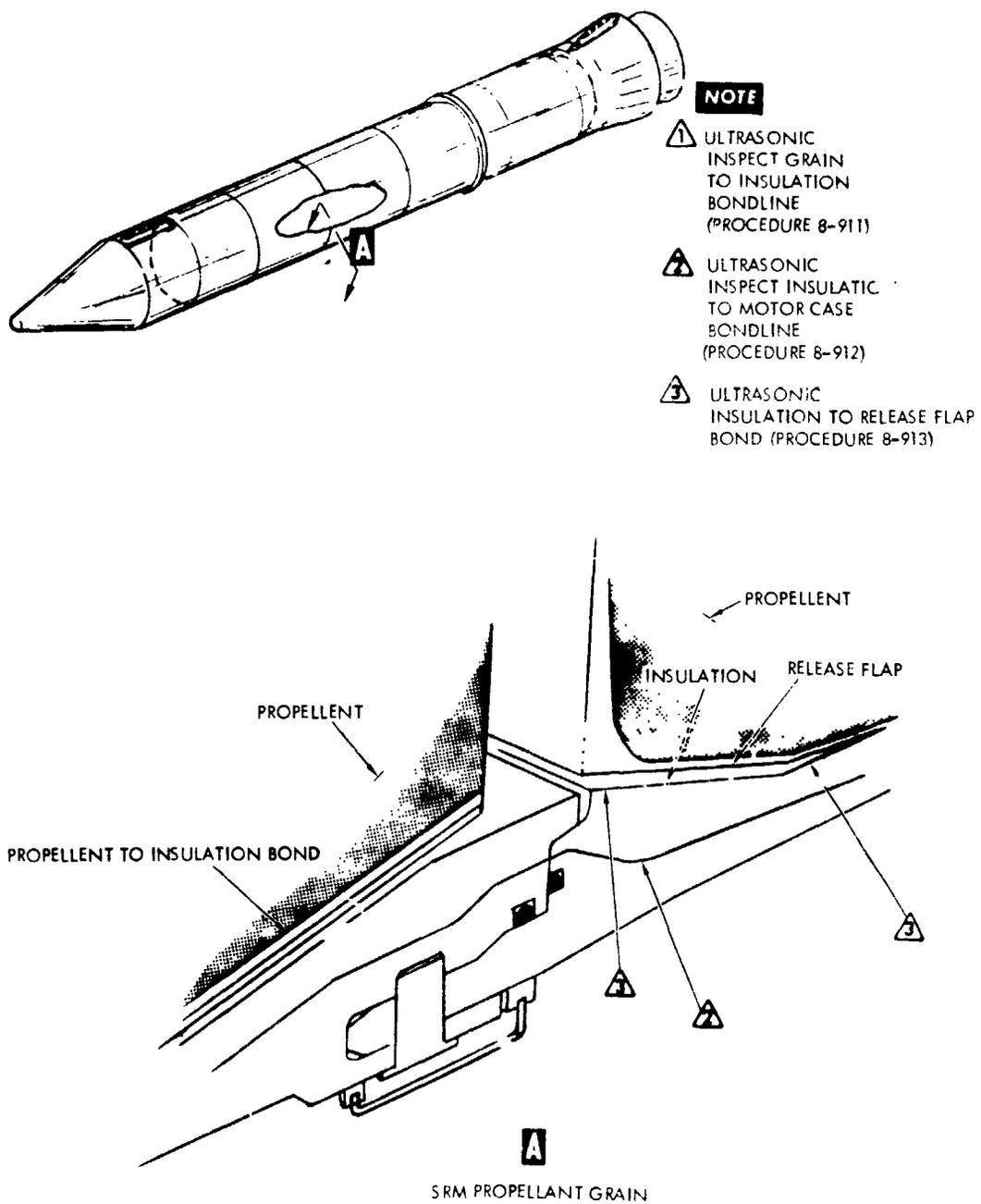
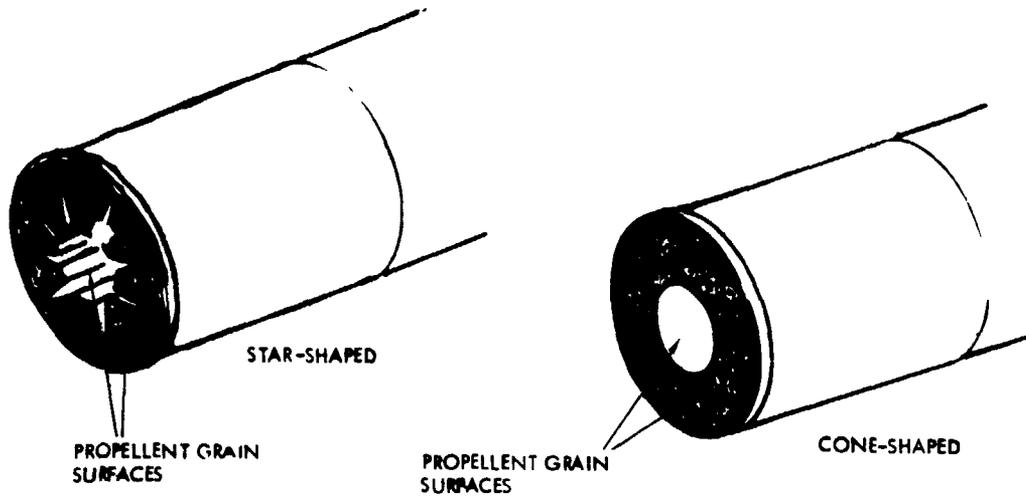


Figure 8-9. Propellant Grain and Case Interfaces (Sheet 1 of 2)



NOTE

OPTICAL
INSPECT PROPELLENT
GRAIN SURFACES
(PROCEDURE 8-910)

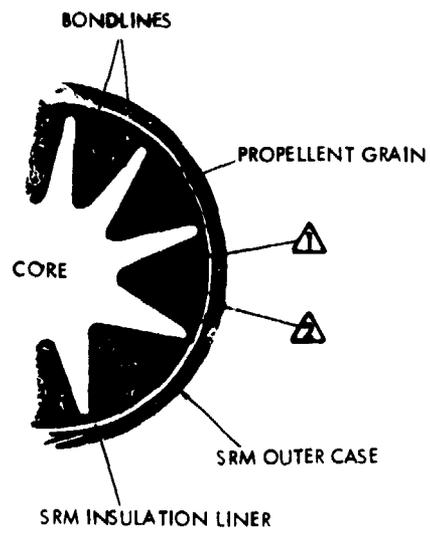


Figure 8-9. Propellant Grain and Case Interfaces (Sheet 2 of 2)

PROCEDURE NO: 8-914, FIGURE 8-10
MAJOR ASSEMBLY: SOLID ROCKET BOOSTER
 ZONE 9
SUBASSEMBLY: AFT ATTACHMENT STATION
DRAWING(S): VL72-000103A
COMPONENT/AREA DESCRIPTION: ET/SRB AFT ATTACH FITTINGS AND TRUSSES.

TYPE INSPECTION:
 (X) POSTFLIGHT
 (X) PREFLIGHT

This fitting is used as a direct attachment point between SRB and ET up to the point of SRB jettison. Booster station X_b 2060 (Orbiter station X_o 1307). This structure located on the SRB is made of titanium (6Al-4V). Shear, tensile and compressive interactions between the ET and SRB at this point due to vibrations during liftoff and ascent, wind gusts, G-loads, and aerodynamic forces, can result in fatigue and/or overload damage in the structure.

DEFECTS: Cracks in the clevis bolt hole of the attach fitting or the truss; also cracks may occur in the lug/base fillet.

ACCESS: The exterior portion of the fitting has ready access in the unmated condition and should be inspected after recovering terminating each SRB mission.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3 B) and fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9).
 Backup: Penetrant or eddy current bolt holes for the clevis bolt holes.

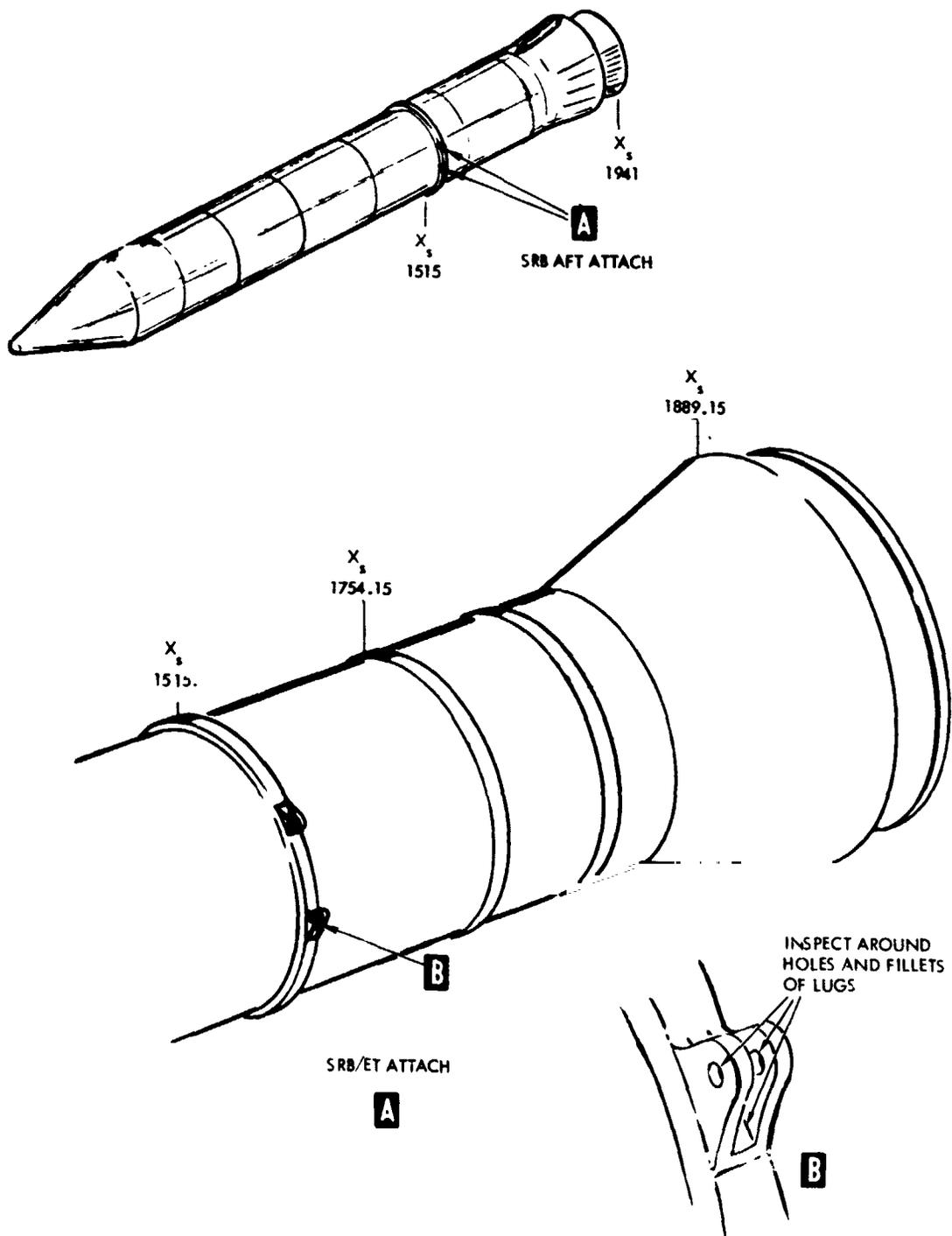


Figure 3-10. ET/SRB Aft Attach Fittings and Trusses

<u>PROCEDURE NO:</u>	8-915, FIGURE 8-11	<u>TYPE INSPECTION:</u>
<u>MAJOR ASSEMBLY:</u>	SRB, AFT STRUCTURE ZONE 9	(X) PREFLIGHT
<u>SUBASSEMBLY:</u>	THRUST VECTOR CONTROL (TVC) STRUCTURE AND ASSEMBLY	(X) POST RETRIEVAL (X) NON CONFORMANCE

COMPONENT/AREA DESCRIPTION: The TVC system provides controlled deflection of the SRM nozzle to effect steering of the boost phase operations in consonance with the orbiter engine operation. The SRB TVC electrical components are contained within the aft SRB structure and interface with the hydraulic actuation servo valve system (2 units) and the power and control lines contained within the SRM raceway. The system includes typical pressure, valve position and fluid level transducers necessary to assess system operational status. The TVC mechanical assembly incorporates the blowdown hydraulic pressurant supply, with associated pressurization and regulation, and two servo-operated hydraulic actuators attached between the SRM nozzle and the SRB aft structure.

DEFECTS: Defects are typical of hydraulic system assemblies and could include mechanical misalignment, binding, hydraulic fluid supply losses, gas system and hydraulic system contamination, defects in highly stressed mechanical interfaces on the nozzle and SRB structure and improper plumbing or mechanical assembly. The actuator attachment arms and fittings may develop cracks due to actuation loads and vibro-acoustics.

ACCESS: During buildup of the SRB aft structure, the hydraulic reservoir and gas pressurant tankage and plumbing is readily accessible. Upon assembly of the SRB aft structure within SRM aft segment, access is limited by the nozzle, hydraulic actuator configuration, intrusion of separation motors and similar assemblies.

NDT TECHNIQUES: Primary: Ultrasonic shear wave (Para. 1.5.5.3. B) for attachment bolt hole on the actuator arms and attach fittings. Fluorescent penetrant (Para. 1.5.2.1, Fig. 1-9) can be used for more general inspection of fitting to motor attach.

PROCEDURE NO. 8-915, FIGURE 8-11 (continued)

Optical alignment equipment should support assembly and provide capability for evaluation of actuation alignment criteria.

DETAILED EVALUATION OF NONCONFORMING CONDITIONS: Checkout tests should reveal leakage, pressure regulation irregularities, valve sticking and similar hydraulic system problems. If the checkout is unsuccessful, the test rig can be utilized in the applicable mode to trace down defects and isolate components for repair or replacement.

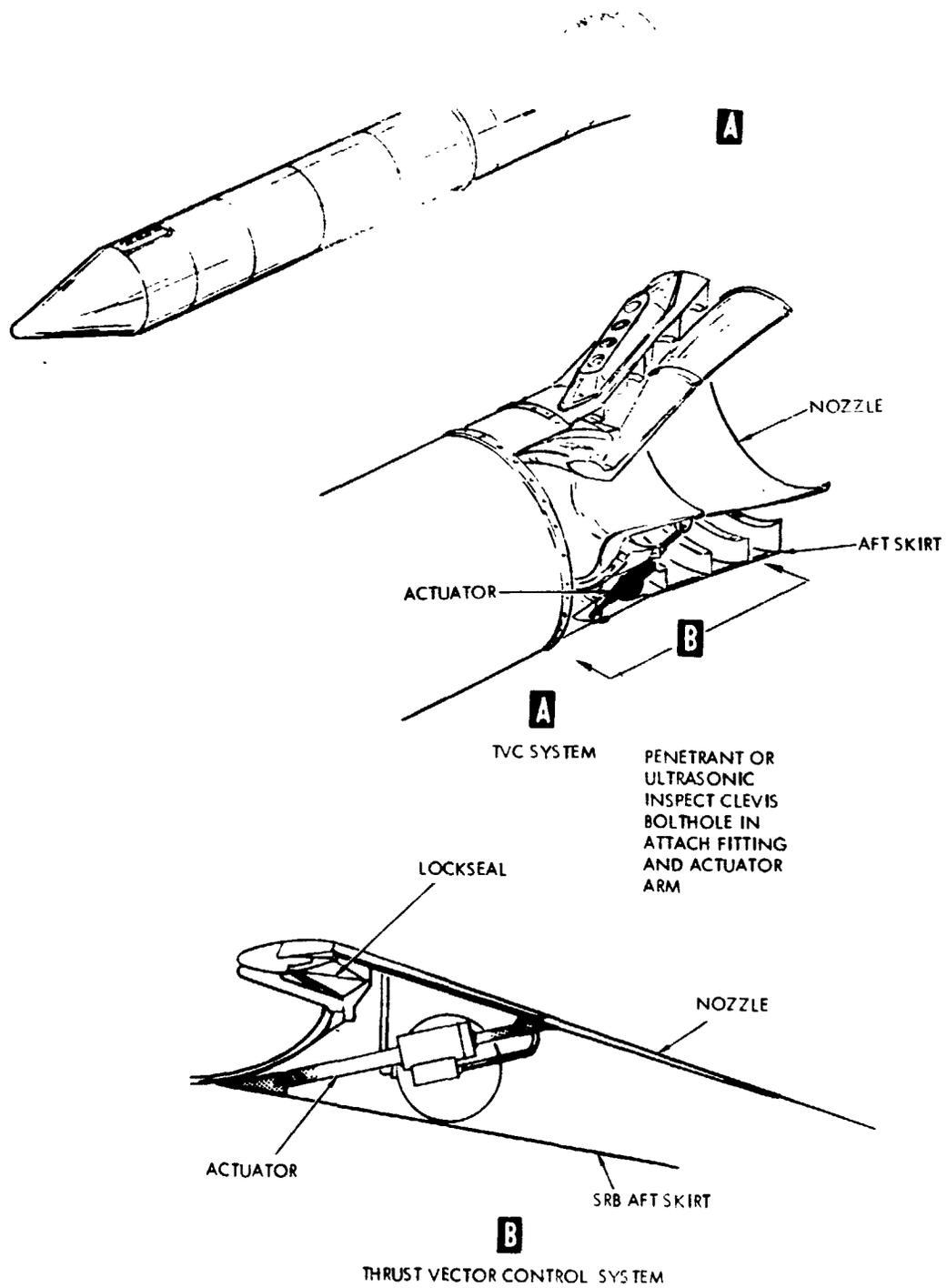


Figure 8-11. Thrust Vector Control Structure and Assembly

PROCEDURE NO: 8-916, FIGURE 8-12

MAJOR ASSEMBLY: SRB, MOVABLE NOZZLE
ZONE 9

TYPE INSPECTION:

(X) PREFLIGHT

SUBASSEMBLY: FLEXIBLE SEAL (TVC)

COMPONENT/AREA DESCRIPTION: Ti. flexible seal is made of metal rings separated by elastomeric pads. A good bond between these segments is essential.

DEFECTS: Poor or weak bonds during manufacturing may separate under prolonged tensile loads of handling and storage.

ACCESS: The steel to elastomer bond line is accessible only at the edge.

NDT TECHNIQUES: The flexible seal should be visually inspected during prelaunch inspection. After assembly into the SRB the flexible seal should be run through the duty cycle that will characterize the mission except that the checkout should be limited to 4 degrees, half of the design vector angle.

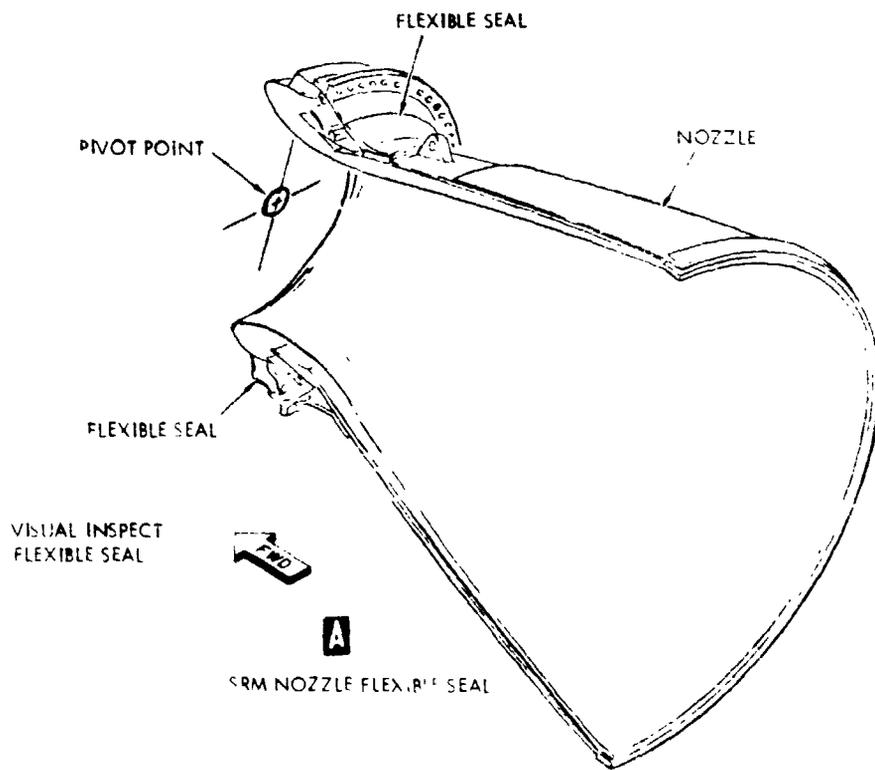
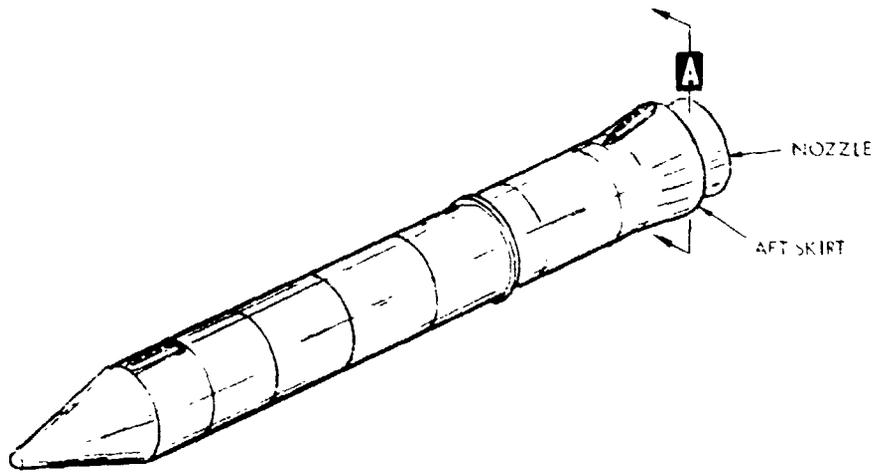


Figure 8-12. Nozzle Flexible Seal

PROCEDURE NO: 8-917, FIGURE 8-13
MAJOR ASSEMBLY: S^{DB}, MOVABLE NOZZLE
ZONE 9
SUBASSEMBLY: NOZZLE SHELL

TYPE INSPECTION:
(X) PREFLIGHT
(X) POST RETRIEVAL
(X) NON CONFORMANCE

COMPONENT/AREA DESCRIPTION: The nozzle shell is a welded high strength steel section which provides strength to react pressure loads and support the ablative plastics. A bolt hole pattern is provided for attachment to the case aft closure, and will also be used to tie down the unit during shipping and storage.

DEFECTS: The nozzle shell is susceptible to scratches, dents, and corrosion pitting during shipping and handling. In addition, the bolt holes may have permanent set due to excessive handling loads. Similar defects can occur during water recovery and retrieval. Since the shell is designed near optimum, defects of this nature can cause failure.

Defects can be detected by standard prelaunch and post retrieval visual inspection of the nozzle. If defects are detected, special nonconformance inspection as described below will be required.

ACCESS: The outside of the nozzle shell and the bolt hole pattern are accessible.

NDT TECHNIQUES: If the standard prelaunch or post retrieval visual inspection reveals defects, the following non-conformance inspection will be required.

Shell Membrane Areas:

1. Fluorescent penetrant inspect (Para. 1.5.2.1, Fig. 1-9) damaged area to determine extent of damage, after removal of protective coating from the area adjacent to the damage.
2. Use an ultrasonic thickness tester (Para. 1.5.5.4) to determine membrane thickness adjacent to the damaged area.

PROCEDURE NO. 8-917, FIGURE 8-13 (continued)

3. After blending or repair of the damaged area, check membrane thickness at base of flaw location by ultrasonic thickness tester.
4. Penetrant inspect defect area to assure complete flaw removal.
5. Recoat area and test thickness of protective coating applied with magnetic or eddy current thickness gage. Type of NDI coating thickness gage will be dependent on type of protective coating used on case exterior.

Bolt Holes :

1. For non-conforming bolt holes, the inside diameter should be inspected using eddy current bolt hole (Para. 1.5.4.3) inspection.

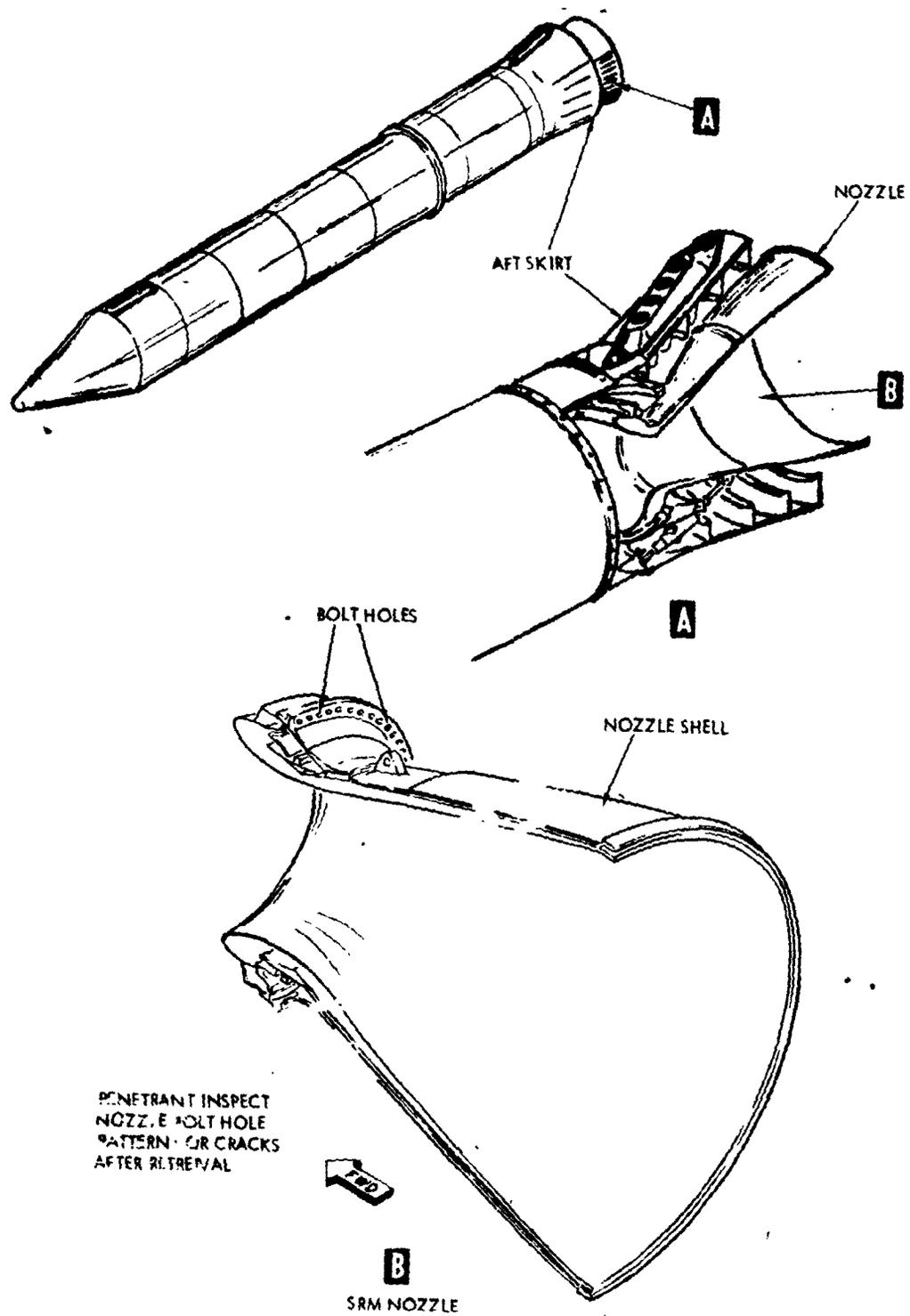


Figure 8-13. Nozzle Shell

PROCEDURE NO: 8-918, FIGURE 8-14

TYPE INSPECTION:

MAJOR ASSEMBLY: SRB, MOVABLE NOZZLE,
ZONE 9

(X) PREFLIGHT

SUBASSEMBLY: NOZZLE ABLATIVES

COMPONENT/AREA DESCRIPTION: The nozzle ablatives form the inside contour of the nozzle which is subjected to the propellant combustion temperatures. If the nozzle ablatives are damaged and are ejected from the nozzle during motor operation or if the alignment is wrong, the correct flight trajectory will not be achieved.

DEFECTS: The throat section of the nozzle must be fitted to the motor such that the proper alignment of motor thrust occurs. This must be measured on all motors.

Defects in the nozzle ablatives such as cracks, voids and unbonds are possible but should be detected by inspection at the vendor's plant.

ACCESS: The nozzle throat is accessible for inspection.

NDT TECHNIQUES: Thrust alignment of the motor to the orbiter will be made by optical measurements. If mechanical tooling is used to support optical targets or locate the centerline of the nozzle and if this tooling is mounted on the nozzle ablative parts, the tooling points of contact with the ablatives should be inspected by the alcohol penetrant method. Otherwise, only visual inspection of the ablatives is required.

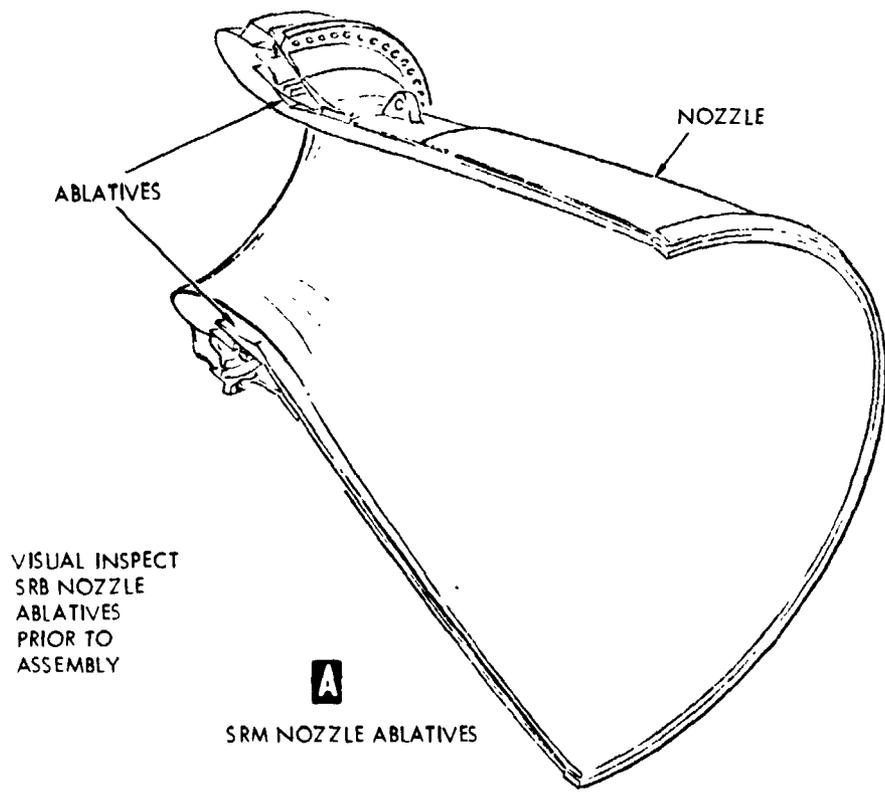
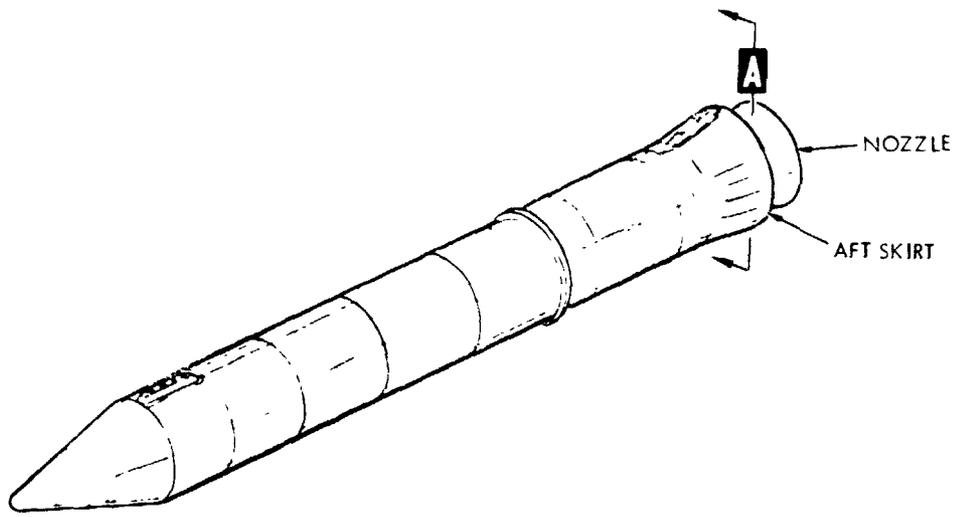


Figure 8-14. Nozzle Ablatives

PROCEDURE NO: 8-919, FIGURE 8-15 TYPE INSPECTION:
MAJOR ASSEMBLY: SRB, ZONE 9 (X) PRELAUNCH
SUBASSEMBLY: SRM JOINT SEALS, LEAK TEST
COMPONENT/AREA DESCRIPTION: Each bolted or pinned joint in the SRM contains O-ring seals. It is anticipated that the majority of the seals will be designed for redundant O-rings. A positive test of the seals (a leak check) following assembly provides an increased confidence in successful performance.

DEFECTS: Basic material defects or defective splices in O-rings should be discovered by the supplier. Small cuts, gouges or crushed areas on the O-ring itself or complete failure to seal the joint can result from improper handling or installation. Failure to seal a SRM joint can cause catastrophic failure and loss of mission.

ACCESS: O-rings as components are accessible for visual inspection. When the O-rings are in place, accessibility for leak check is only through a test medium such as pressurized gas.

NDT TECHNIQUES: Several techniques of leak check are available. No one method is recommended, however, the physical size of the SRM effectively precludes practical utilization of some of the methods considered standard on smaller devices.

The primary candidates for leak test of SRM joints are:

- 1) Low pressurization of the SRM case and observations of joints externally;
- 2) Evacuation of joint area exterior and evaluation of joint leakage, and;
- 3) Pressurization (or evacuation) of the space between O-rings.

Use of sniffer elements such as helium or halogens in the pressurant of Method 1 is probably cost prohibitive. Method 1 or 2 could utilize an off-gassing grease as shown to aid sniffer detection. Method 3 could use full SRM pressure but operates one O-ring in the wrong direction. Method 3 offers the highest probability of detection of leakage

PROCEDURE NO: 8-919, FIGURE 8-15 (continued)

when used at high pressure. It does require specific design features in the SRM case, but avoids the need for a nozzle pressure closure as in Method 1 or other leak sources as in Method 2.

Non-conformance, i.e., a leak, requires re-opening of the joint. For this reason, the method selected should be positive in detection and avoid marginal or doubtful results that could result in unnecessary operations.

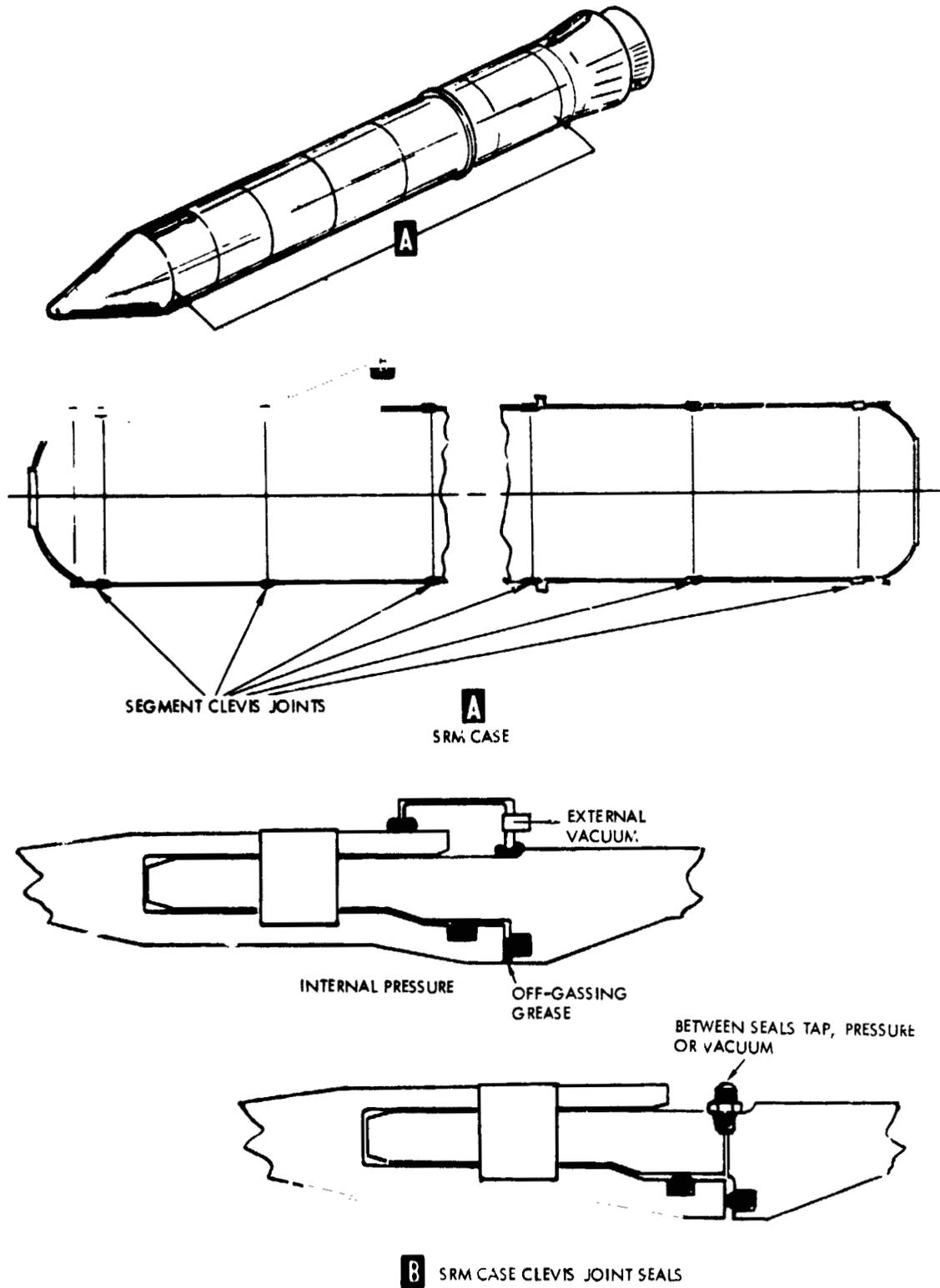


Figure 8-15. SRM Segment Joint Pressure Seals

SECTION 9. THERMAL PROTECTION SYSTEM

The section describes, for the purpose of further development, the NDE requirements for the reinforced-carbon/carbon (RCC) leading edges and the high-temperature and low-temperature coated reusable surface insulation (HRSI and LRSI, respectively).

The NDE techniques listed for each system are those which appear applicable at present to accomplish the inspection task given, but further development is needed to prove feasibility and/or develop validity and high reliability.

SECTION 9
TABLE OF CONTENTS

<u>Procedure Number</u>	<u>Title</u>	<u>Page</u>
9-1001	Reinforced Carbon/Carbon (RCC) Leading Wing Edges and Forward Fuselage Nose Cap	9-1
9-1002	Coated Ceramic High-Temperature Reusable Surface Insulation (HRSI) and Low-Tempera- ture Reusable Surface Insulation (LRSI)	9-11

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SECTION 9
LIST OF FIGURES

<u>Figure Number</u>	<u>Title</u>	<u>Page</u>
9-1	RCC/TPS Applications	9-7
9-2	RCC Wing Leading Edge and Nose Cap	9-8
9-3	Orbiter Isothermal Diagram	9-10
9-4	HRSI/TPS and LRSI/TPS Applications	9-18
9-5	Shape, Size and Quantity of RSI/TPS Tiles for Five Orbiters	9-19

<u>PROCEDURE NO:</u>	9-1001 NDE DEVELOPMENT AREA FIGURES 9-1, 9-2 AND 9-3	<u>TYPE INSPECTION:</u> (X) POST FLIGHT (X) PREFLIGHT
<u>MAJOR ASSEMBLY:</u>	ORBITER, LEADING EDGES, ZONES 2 AND 6	
<u>SUBASSEMBLY:</u>	THERMAL PROTECTION SYSTEM (TPS)	

COMPONENT/AREA DESCRIPTION: REINFORCED CARBON/CARBON (RCC) LEADING WING EDGES AND FWD FUS NOSE CAP. The Orbiter wing leading edges, including the wing glove leading edges, and the forward fuselage nose cap consist of molded panels of carbon fiber reinforced carbon epoxy matrix which form rigid, high-temperature-resistant aerodynamic foils, as illustrated in Figure 9-1. The system is further coated with, or contains an intrinsic, oxidation inhibitor to prevent surface chemical degradation at high entry temperatures. This system is part of the Orbiter thermal protection system (TPS) designed to protect the metal leading edge structure from the highest temperature expected to be encountered during vehicle ascent and entry into the atmosphere from orbit - between 2300°F and 3000°F. The RCC leading edge panels are attached to the wing leading edge spar with titanium alloy trusses, brackets and fittings such as shown in Figure 9-2. They are reinforced by formed rib stiffeners inside the leading edge cavity. The RCC panels interface with HRSI/TPS panels which protect wing and fuselage surfaces in the range of 1200°F to 2300°F. The Orbiter entry isothermal lines are shown as degrees Fahrenheit in Figure 9-3.

In addition to accepting the high heating loads, the RCC panels must also maintain an aerodynamically viable leading edge shape during and subsequent to the atmospheric entry flight phase. The wing leading edge panels have chordwise contours, but typically are straight along the leading edge. The nose cap resembles a cone with an extended portion on the lower surface of the fuselage.

RCC composites which comprise the leading edges are heterogeneous, two-phase materials whose strength and modulus depend on the directional reinforcement fibers and the shear or binding properties of the matrix. The mechanical properties

PROCEDURE NO. 9-1001 (continued)

may, therefore, be anisotropic, depending on the relative percentage of fibers in a given direction. The coefficient of thermal expansion is also influenced by filament orientation due to the filaments having a smaller linear expansion than the matrix. Graphites are brittle materials that do not normally exhibit plastic flow or yielding prior to fracture.

Unprotected RCC materials tend to oxidize in the presence of air at high temperatures. Oxidation causes degradation in mechanical and thermophysical properties, rendering the material unsuitable for reuse. Protection against oxidation is provided through the use of an oxidation-inhibitor which is coated onto the material surface or integrated into the material itself. An oxidation inhibitor coating must provide an impervious, non-oxidizing, homogeneous barrier to exclude oxygen from the carbon. The coating must be compatible with the carbon in terms of thermal expansion and chemical stability to prevent degradation and spall-off. The integrated inhibitor system comprised of impregnated ceramic powders may produce some problems due to dispersion nonuniformity, but does not introduce some problems characteristic of coatings.

Deflections and strains are transmitted to and from the RCC leading edges and airframe structure during all flight regimes - launch, staging, on-orbit thermal cycling, entry, cross-range flight, ferrying and landing. The stress system in the leading edge changes continuously during heating or cooling. Due to the brittle, non-plastic nature of RCC materials, the role of discontinuities, even in their nucleated phase, under severe thermomechanical loads are of special concern.

Fracture may occur when the material experiences sudden cooling from a uniform high temperature, which produces tensile stresses in the material - the primary fracture mode. Sudden heating places the surface in compression so that fracture in this state would occur in a non-surface location. During entry, thermally

PROCEDURE NO. 9-1001 (continued)

induced stresses will be relatively severe. While heating during this period, the expansion of the outer surface of the material will induce tensile stresses on the cooler inner surface, potentially causing inside-surface fractures or internal delaminations.

A tensile stress state may be imposed on the outer surface of the RCC leading edges during the latter stage of entry when the Orbiter experiences the cool stratosphere. At peak heating, the back surface of the leading edge is expected to attain a high temperature. The outer surface is most prone to fracture during the outer cooling phase.

Recession, or erosion, of the RCC outer surface or oxidation-inhibitor coating, may be produced by atmospheric ice, dust or rain. The material loss must be measurable by NDE techniques to provide refurbishment data.

The leading edge shape must be maintained to function effectively as an aerodynamic structure. Material flow at high temperatures can produce deformation leading to reduced aerodynamic characteristics. Some RCC materials do become plastic at high temperatures and deform under dynamic pressure loads. Upon cooling from this plastic phase, a deleterious stress system may be frozen in, affecting both inhibitor coating and the RCC panel.

Chemical degradation due to oxidation and physical degradation due to delaminations, microcracks and repetitive thermal cycling may affect the mechanical and thermophysical properties of the RCC material.

Damage and degradation of the RCC components may accumulate with each flight. The effects of repetitive flight cycles on previous damage in terms of flaw initiation and propagation and property damage requires assessment through a rigorous inspection routine.

PROCEDURE NO. 9-1001 (continued)

DEFECTS: Defects relative to the RCC materials can be described in terms of 1) geometrical flaws and 2) property degradation through chemical or phase changes.

Geometrical defects that may be produced in the RCC leading edges by the full flight load regime in combination with environments include:

- a. Formation of microcracks,
- b. Fractures, outer and inner surfaces,
- c. Internal delaminations,
- d. Recession (erosion) of the outer surface due to abrading environments,
- e. Spalling of outer surface oxidation-inhibitor coating, if present, and
- f. Deformation (changes in contour) due to high-temperature flow.

Property changes or non-geometrical defects include:

- a. Oxidation,
- b. Loss in thermal and thermomechanical properties, and
- c. Crystalline phase changes due to repeated thermal cycles.

ACCESS: The wing leading edges and the forward fuselage nose cap are exterior aerodynamic surfaces readily accessible when the Orbiter is in the horizontal parked position. Work platforms will be needed to facilitate inspection. Removable upper leading edge access panels just aft of the RCC panels permit entry into the leading edge cavity for access to the back side of the RCC panels. Internal insulation may have to be removed for additional access. The RCC/TPS panels themselves are removable so that they may be taken to a laboratory for detailed inspection.

NDT TECHNIQUES: Refurbishment techniques for adequate inspection and evaluation of the RCC leading edge panels are subject to further development and refinement. In addition to the techniques, an inspection routine should be established which shall effectively arrange and use the applicable NDT disciplines to supply the maximum amount of data relating to the integrity of the RCC components. Applicable techniques for detecting and characterizing the possible service defects are summarized in the following table.

RCC TPS DEFECTS AND NDT TECHNIQUES

DEFECT	NDT METHOD	NDT TECHNIQUE
Surface crack external	Visual Penetrant Ultrasonic Radiographic Eddy Current	Eyeball Alcohol wipe or filtered particle Shear wave or surface wave pulse echo X-ray Low-conductivity/high-frequency instrument
Surface crack, internal	Ultrasonic Radiographic Penetrant	Shear-wave or surface wave pulse echo X-ray Filtered particle
Internal delamination	Ultrasonic	Resonance (thickness measuring)
Microcrack	Penetrant Ultrasonic	Alcohol wipe Surface-wave pitch/catch (attenuation)
Recession (erosion)	Ultrasonic Radiographic	Resonance (thickness measuring) Film density/attenuation
Deformation	Straight-edge or contour templates Holography	Comparison Interferometry

(continued)

PROCEDURE NO. 9-1001 (continued)

RCC TPS DEFECTS AND NDT TECHNIQUES

DEFECT	NDT METHOD	NDT TECHNIQUE
Oxidation	Eddy current Radiometry	Low conductivity measurement Gamma-ray absorption
Thermal degradation	Thermal measurements	Thermal conductivity, diffusivity, expansion, reflectance, capacity, etc.
Mechanical properties	Ultrasonic Radiometry	Velocity Gamma ray absorption/attenuation

The NDE development plan has been described in the accompanying report.

TPS APPLICATIONS

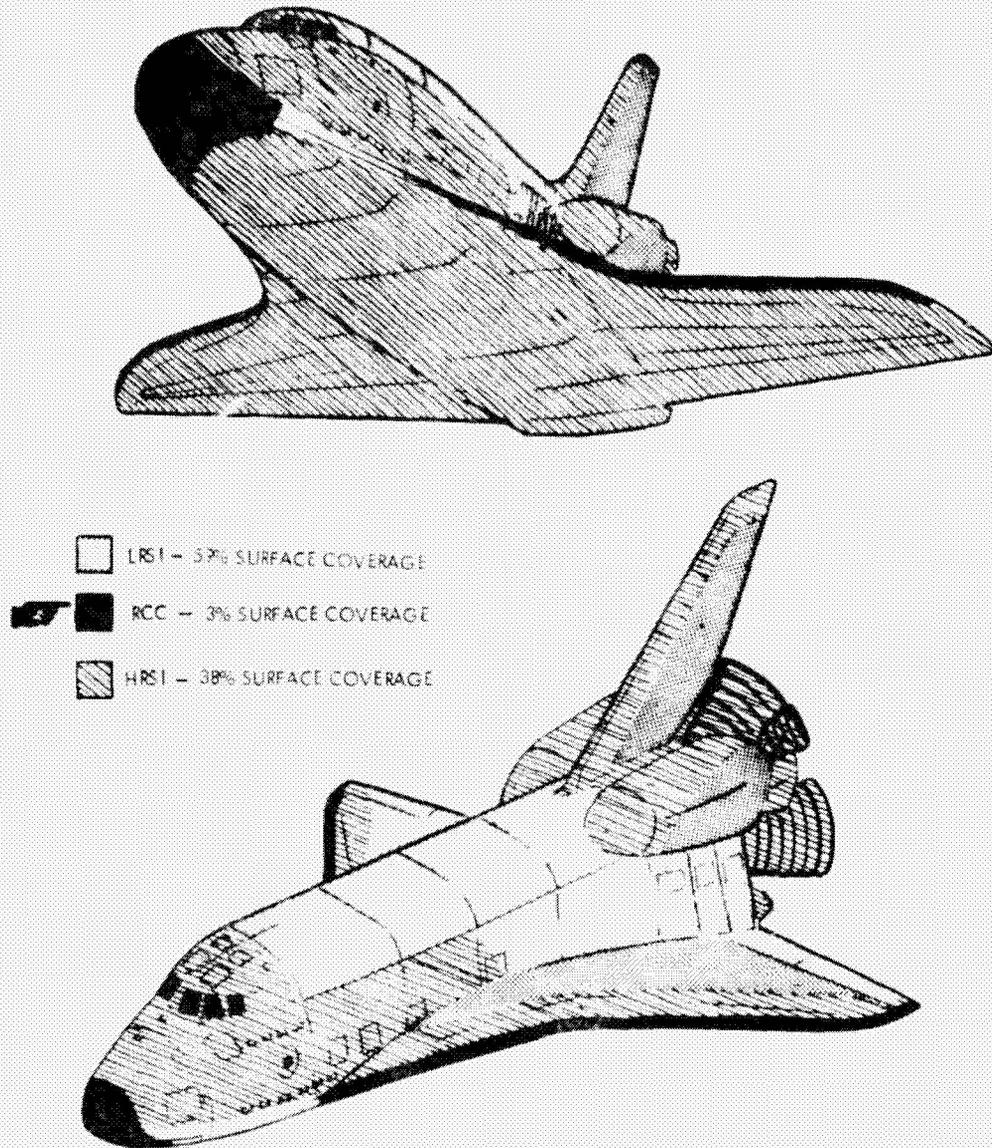
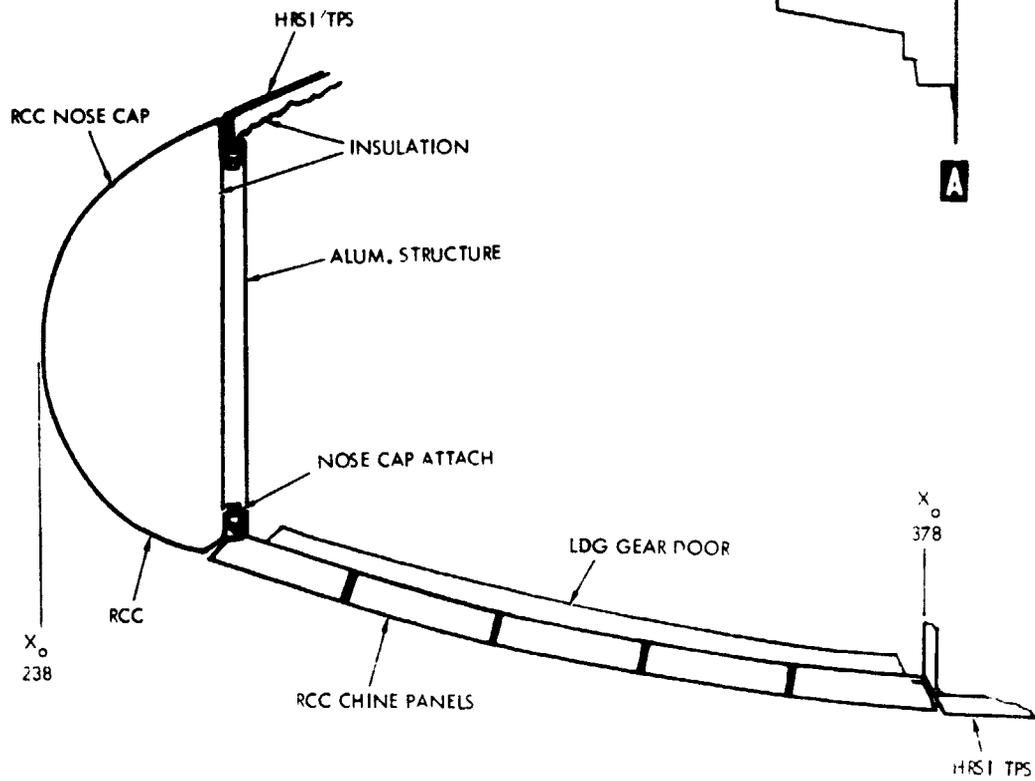
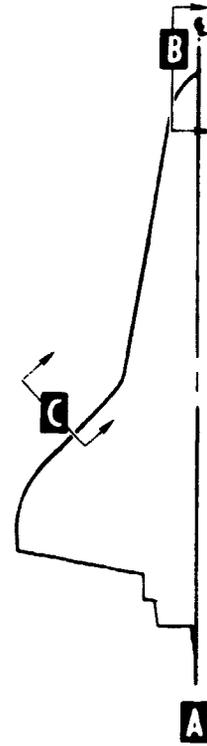
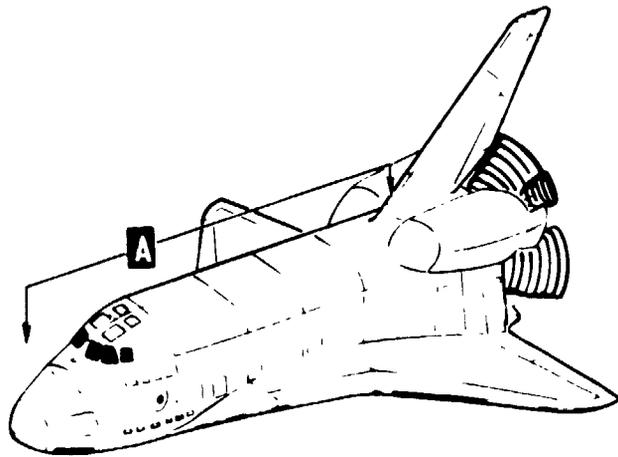
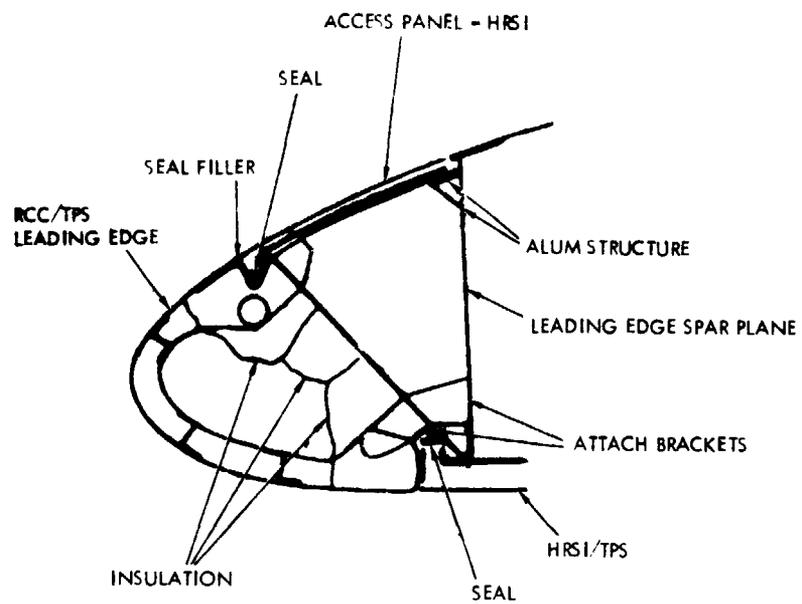


Figure 9-1. RCC/TPS Applications



B RCC /TPS NOSE CAP AND CHINE PANELS

Figure 9-2. RCC Wing Leading Edge and Nose Cap (Sheet 1 of 2)



RCC/TPS WING LEADING EDGE

Figure 9-2. RCC Wing Leading Edge and Nose Cap (Sheet 2 of 2)

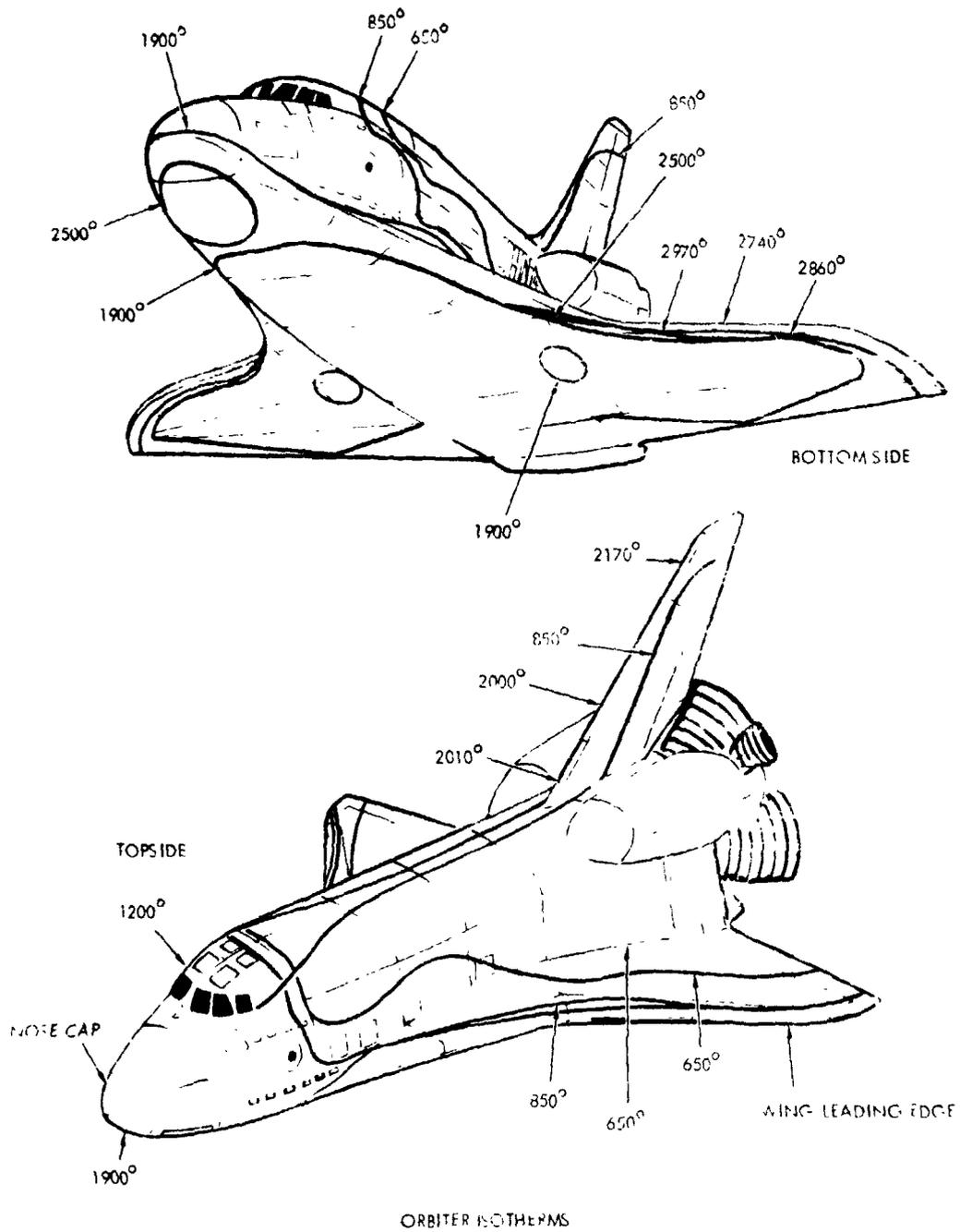


Figure 9-3. Orbiter Isothermal Diagram

<u>PROCEDURE NO:</u>	9-1002 NDE DEVELOPMENT AREA FIGURES 9-4 AND 9-5	<u>TYPE INSPECTION:</u> (X) POSTFLIGHT (X) PREFLIGHT
<u>MAJOR ASSEMBLY:</u>	ORBITER, ALL SURFACE AREAS OTHER THAN LEADING EDGES AND FWD FUS NOSE CAP	
<u>SUBASSEMBLY:</u>	THERMAL PROTECTION SYSTEM (TPS)	

COMPONENT AREA/DESCRIPTION: COATED CERAMIC HIGH-TEMPERATURE REUSABLE SURFACE INSULATION (HRSI) AND LOW-TEMPERATURE REUSABLE SURFACE INSULATION (LRSI). All exterior surfaces of the Orbiter vehicle are covered with a low-density ceramic insulation material to protect the metal structure from high-temperature reaction with the atmosphere during ascent and entry, as shown in Figure 9-4. The HRSI and LRSI are made from a high-purity, amorphous, short-staple silica fiber dispersed into an aqueous slurry which is dried and compacted in a frame caster to produce blocks of material having the desired density. A silica binder is introduced by capillary action and the block is over-dried and sintered. Rough and precision sawing to size is done and the blocks are ground to final shape and surface finish. A semi-permeable surface coating is applied and sintered to provide a water-proof, high-emissivity radiation control surface. The material is commercially known as LI-900 RSI.

The RSI tiles are cut and ground to the desired geometric shape and thickness, RTV-bonded to a felt strain-isolation pad, and RTV-bonded directly to the airframe surface as illustrated in Figure 9-5. Density of the material is typically 9 pounds per cubic foot except in areas where damage may occur where it has a density of 30 pounds per cubic foot. Since the entire vehicle surface must be protected, special provisions are made for penetrations into the airframe such as landing gear doors, crew hatch and access panels, control surface interfaces, and intervehicular attachments.

The RSI materials are provided in a variety of flat, simple curved, or double-contoured shapes to accommodate the exterior shape of the airframe at its intended

PROCEDURE NO. 9-1002 (continued)

location (refer to Figure 9-5). The thickness and surface coating of the tiles are determined by entry surface isothermals illustrated in Figure 9-3 and the requirement to limit the maximum airframe surface temperature to 350°F.

The HRSI/TPS panels are installed on the airframe surface where entry operating radiation equilibrium temperatures are expected to range between 1200°F and 2300°F. The LRSI/TPS panels, having a different surface coating, are installed where entry radiation equilibrium temperatures are expected to range below 1200°F. High risk areas due to high-temperature exposure and the potential for damage from debris and other means are identified. Since the RSI is semi-permanently bonded to the exterior surface, it will provide access problems for inspection of airframe components, particularly skin panels.

In addition to protecting the airframe from high-temperatures, the RSI/TPS also interfaces directly with the aerodynamic environment and transfers air pressures to the skin. The strain-isolation pad (SIP) serves to accommodate the rigid RSI tiles to small surface irregularities such as rivets and to small strains and deflections produced during flight. The SIP is necessary since RSI materials have low mechanical and thermo-physical property values relative to the airframe properties. However, the materials have excellent thermal stability under repeated heat cycles.

The primary failure modes for the RSI are related to coating integrity and compatibility to strain between the RSI panels and the airframe structure to which they are bonded. Due to the critical function of these materials in protecting the aluminum skin, it is extremely important that the integrity of the coating and panel/skin bonding be maintained throughout the mission.

Failure of the emissivity coating can lead to moisture absorption and to loss of effective radiative heat control. Moisture absorption causes weight increase and

PROCEDURE NO. 9-1002 (continued)

possible tile damage due to freezing and/or rapid steam production. Loss of radiative heat control may cause overheating in the skin. Coating failures may be caused by cracks, erosion, abrasion, pitting and degradation due to contamination.

Failure in the RSI material and bonding are primarily associated with incompatible strain accommodation between the RSI and airframe. The critical strain at the RSI/airframe interface is defined by the airframe contractive stresses during cold soak in orbit. Since the bonded RSI adds negligible stiffness to the structure, critical interface strains can also be caused by loading of the structure. The RSI failure stress state could be tension perpendicular to the bondline, bondline shear, or outer surface tension. These conditions can be caused by airframe deflections, and thermal expansion or contraction in excess of the ability of the RSI panel to accommodate it. The use of individual RSI tiles in small (6" x 6") configurations greatly reduces the potential of failure due to deflections.

Two critical thermal stress modes for the RSI occurring during and after entry have been defined as 1) the earliest point of peak surface heat-up rate and 2) the point of peak bondline temperature. In the first mode, a large temperature gradient in the RSI will set up a differential expansion between the strained outer surface and the unstrained bondline. In the second mode, when the bondline is at its maximum temperature, the RSI outer surface is relatively cool. The expansion of the airframe causes a high strain in the bondline which is accommodated somewhat by the strain isolation pad. The bondline strain is similar to that produced by flexure. Tensile and shear strains produced across the bondline can result in edge debonds and interlaminar separations near the bondline.

Coating failure. Surface degradation occurs when sufficient damage has been done to the coating to decrease surface emittance, allow moisture absorption, or prevent outgassing in space vacuum. This damage can include microcracks, exfoliation,

PROCEDURE NO. 9-1002 (continued)

pitting and erosion or contamination and chemical degradation. A high-surface emissivity is necessary to limit the surface temperature by re-radiating most of the surface heat into space. During high heating rates, only a small proportion of the surface heat is conducted toward the airframe. Surface tensile strains, flexure handling, and atmospheric rain, ice and dust may damage the coating, or it may be contaminated by cleaning compounds, leakages, or oil.

RSI failure. Although some types of stable cracks in the RSI material may be acceptable, any crack that leads to the loss of chunks of material and deterioration of aerodynamic shape should be cause for rejection. Peeling and delamination cracks, particularly at the edge of the tile, that allow the panel to lift from the airframe surface during flight and present an uneven surface for airflow, should be rejected. Debonds are critical in the sense that they may allow the RSI tiles to lift from the surface and disrupt the airflow or lead to loss of the tile. Bond perfection may not be as critical at tile mid-span as at the edges. Generally the same considerations that apply to delamination cracks also apply to debonds. The loss of an RSI tile or chunks of a tile can be serious and should be prevented through inspection and maintenance. Since the cured RTV adhesive is several times stronger than the internal cohesiveness of the RSI tile, debonds will probably occur less frequently than delaminations.

The RSI tiles may accumulate damage on each flight. Surface microcracks may lead to coating loss or to cracks within the RSI tile, as well as allow moisture infiltration. Any crack, debond, or delamination may grow under the influence of flight loads. Reliable post-flight inspection must be applied to locate and characterize damage to the RSI material, its coating or bondline.

DEFECTS: Defects relative to the HRSI or LRSI materials can be described in terms of 1) geometric flaws and 2) quasi-geometric or degradation changes.

PROCEDURE NO. 9-1002 (continued)

Potential Geometric defects include the following:

- a. Cracks in the surface coating,
- b. RSI cracks perpendicular to the surface,
- c. Near-bondline delaminations at panel edges or midspan,
- d. Debonds at the panel/airframe interface, and
- e. Impact or handling damage and inclusions.

Property or quasi-geometrical changes may include:

- a. Spalling of surface coating,
- b. Microcracks in surface coating,
- c. Moisture infiltration into RSI tile, and
- d. Contamination or degradation of coating or tile.

ACCESS: The HRSI/LRSI panels are attached to the exterior surface of the Orbiter and are readily accessible with the aid of work platforms when needed.

NDT TECHNIQUES: Refurbishment techniques for inspection and evaluation of RCC leading edge panels are subject to further development and refinement. In addition to the techniques, an inspection routine should be established which shall effectively arrange and use the applicable NDT disciplines to supply the maximum amount of data relating to the integrity of the RSI tiles. Applicable techniques for detecting and characterizing the possible service defects are summarized in the following table.

PROCEDURE NO. 9-1002 (continued)

HRSI AND LRSI TPS DEFECTS AND NDT TECHNIQUES

DEFECT	NDT METHOD	NDT TECHNIQUE
Gross defects (large cracks debonds, delam- inations, water infiltration, contamination, emissivity loss, inclusions)	Infrared Visual	Scanning (restricted to tiles less than 0.6 inches (15.24mm) thick for debonds and delaminations) Eyeball!
Surface Cracks	Penetrant Ultrasonic	Filtered particle penetrants Acetaldehyde Penetrant Surface wave, pulse-echo, ASR
Internal Cracks	Ultrasonic Infrared	Acoustic Sonic Ringing (ASR) Shear wave Scanning
Delaminations and Debonds	Ultrasonic Sonic Infrared	ASR Resonance Scanning
Moisture Infiltra- tion	Microwave Capacitance	Moisture gaur. Low-frequency planar capacitance probe
Inclusion (ground debris)	Infrared Radiographic	Scanning X-ray
Coating microcracks	Penetrant Ultrasonic	Filtered particle Alcohol wipe test Surface wave pitch-catch (attenua- tion)
Coating spalling	Capacitance	High-frequency planar probe
Coating Contamina- tion	Capacitance Visual	High-frequency planar probe Discoloration or reflectance change
Coating Emissivity	Microwave, laser	Reflectivity

PROCEDURE NO. 9-1002 (continued)

ORBITER STRUCTURE/TPS CONFIGURATION

STRUCTURAL SUBSYSTEM	EXTERNAL STRUCTURE		TPS	
	Skin	Thickness Inches (mm)	Type	HRSI Thickness LRSI Inches (mm)
Forward Fuselage	Skin/ Stringer Int. Mach.	.025-.040 (0.635- 1.016mm)	RCC Nose/ Bottom	0.530 to 2.570 (13.46 to 65.28)
Mid Fuselage	Int. Mach.	.040-.080 (1.016- 2.032mm)	LRSI HRSI	0.33 to 1.71 (8.38 to 43.40)
Aft Fuselage	Int. Mach.	1.50 (38.1mm)	HRSI LRSI	0.20 to 0.30 (5.08 to 7.62)
Wing	Skin/ Stringer	0.40 (1.016)	RCC/L.E. HRSI Top LRSI HRSI Bottom LRSI	0.420 to 1.010 (10.67 to 25.65) 0.150 to 4.60 (3.81 to 116.8)
Vertical Stabilizer	Skin/ Stringer Honey- comb Rudder	0.050 (1.270)	 HRSI LRSI	 0.430 to 1.950 (10.92 to 49.53)
Cargo Bay Doors	Honey- comb	0.700 (1.778)	HRSI LRSI	1.980 to 3.550 (50.29 to 90.17)
OMS Module	Int. Mach.		HRSI LRSI	1.910 to 2.000 (48.5 to 50.8)

Int. Mach. - Integrally machined
 SIP Thickness .090 for flush areas
 .160 for protruding rivet areas

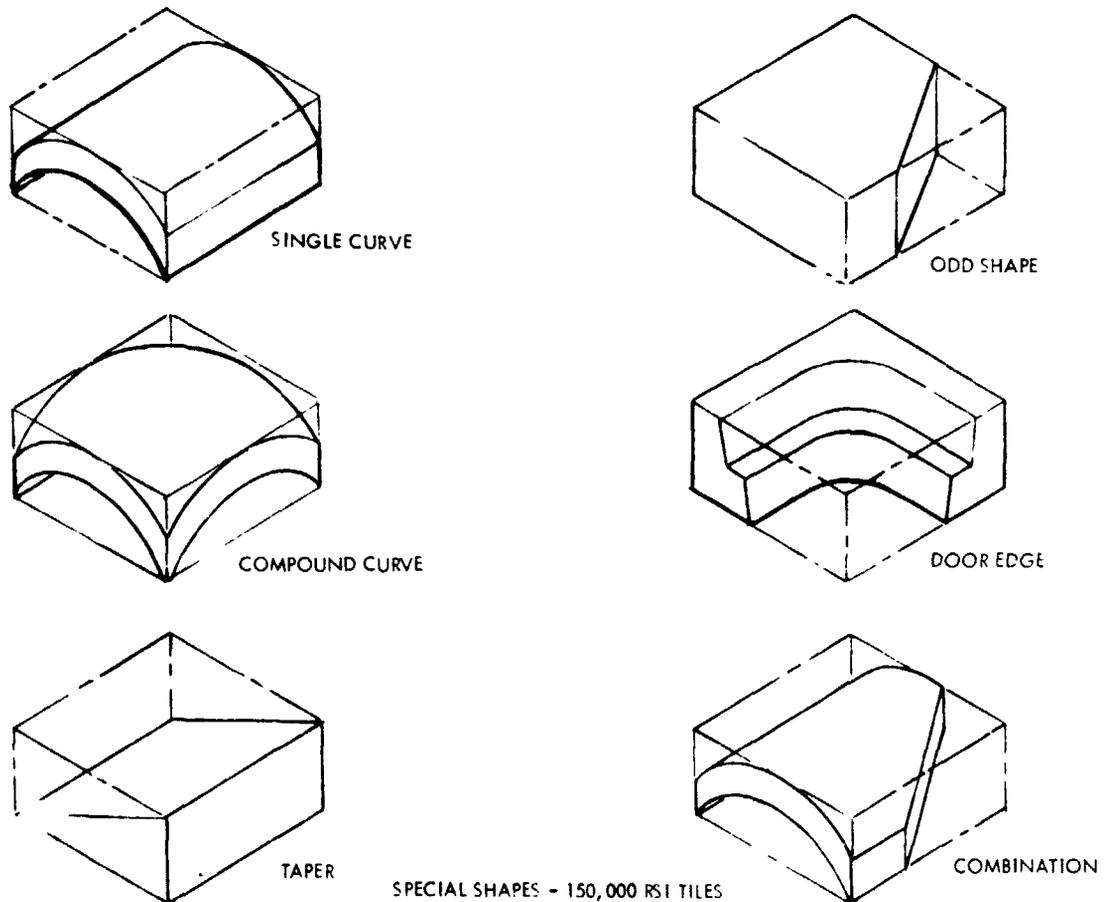
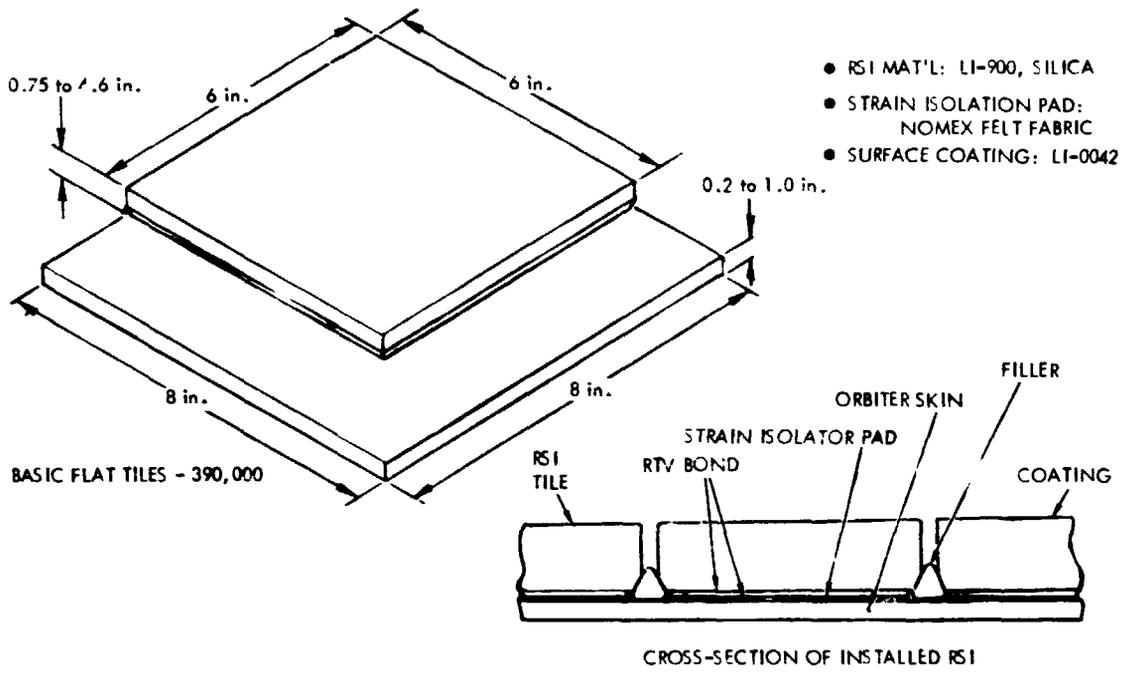
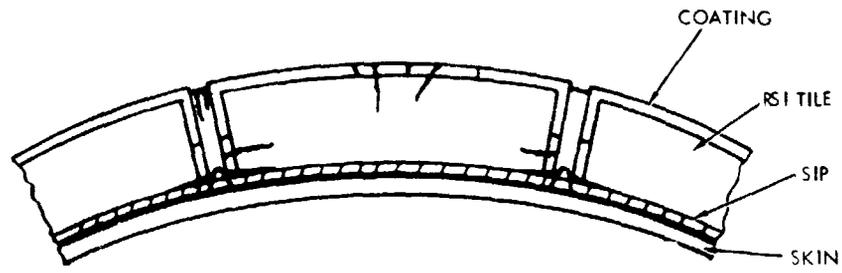


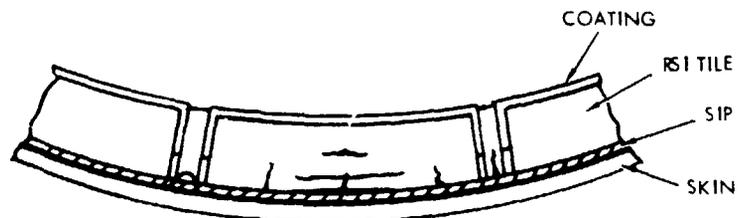
Figure 9-5. Shape, Size and Quantity of RSI/TPS Tiles for Five Orbiters
(Sheet 1 of 2)



DOWN BENDING MODE:

COATING CRACKS
 VERTICAL SURFACE CRACKS
 EDGE DISBONDING
 HORIZONTAL SHEAR CRACKS

EXAGGERATED STRAINS



UP-BENDING MODE:

COATING SPALLING
 ADHESIVE DEBONDS AT CENTER
 PANEL DELAMINATIONS NEAR BONDLINE
 HORIZONTAL SHEAR CRACKS AT EDGE
 PANEL DELAMINATIONS NEAR MIDDLE

Figure 9-5. Shape, Size and Quantity of RSI/TPS Tiles for Five Orbiters
 (Sheet 2 of 2)